Hand Book of Natural Gas

HAND BOOK
OF
NATURAL GAS

By

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PREFACE

The great success met with in publishing the first and second editions of Hand Book of Natural Gas has caused us not only to continue the work, but to endeavor to make this edition greater and better than any previous publication issued by us.

Many articles that were not deemed absolutely necessary to the gas business have been eliminated, and great care has been used in the selection of new subjects.

All material appearing in other editions has been revised and errors corrected.

It is the policy of author and publisher to make these books of general interest to the gas fraternity, in addition to the publishing of necessary data, tables, etc., consequently it is suggested that the original editions be retained by their owners.

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PART ONE

GENERAL

GEOLOGY—ORIGIN OF NATURAL GAS AND OIL —VOLCANIC THEORY—POWER OF NATURAL GAS—GAS VOLUMES—RELATION OF NATURAL GAS TO THE CRACKS AND CANYONS OF ARIZONA—EXHAUSTION OF OHIO'S NATURAL GAS RESOURCES—PRODUCTIVE NATURAL GAS HORIZONS—HISTORY—PRODUCTION OF NATURAL GAS.

In view of the many theories that have been advanced regarding the original source of natural gas, we herewith submit a paper written by the late Frank Westcott, of Alden, New York, who made a life work of the study of natural gas from a geological standpoint. His observations were obtained from a study of rock formations, as well as the logs of many gas wells throughout western New York, Pennsylvania, Ontario, Ohio and West Virginia, and several other states.

The paper is advanced to place before the gas fraternity a reasonable view, not only of the possible source of natural gas, but also of the geological formation of the earth.

The Earth's Formation Briefly Told—"What we now call the earth was, in the beginning, a gaseous body or a molten chaotic mass probably thrown off by some planet, that through a long process of cooling gradually took shape as a globe with a thin, hard crust.

The hard crust, which was of slight thickness in the beginning, but increasing as ages passed, was made up principally of granite formation commonly spoken of as the floor of the earth. At this period there was neither animal

nor vegetable life existing, as the heat was too intense; gas and oil were out of the question.

The transformation from a gaseous body to a hard-crusted globe probably covered a period of many millions of years. During this period there were no mountains nor rivers, and the earth had not begun to shrink.

As ages passed and the globe cooled sufficiently to allow precipitation of the vapor surrounding it, the Potsdam and the Trenton rocks began to form on top of the granite, in the order named. The earth began to shrink, and it was this shrinking of the crust, due to its loss of heat, that created the mountain ranges and the high elevated plateaus, and brought to the surface portions of the lower layers of the earth's crust, carrying with them the metals now being mined. Had this upheaval not taken place, these metals could never have been reached.

The earth's crust is supposed to be from twenty-five to thirty-five miles thick. The increase of temperature toward the interior varies at different points on the globe, as shown by tests made in mining shafts and deep wells. At Butte, Montana, the copper mining shafts show an increase of 1 deg. for each 52 feet descent. The average increase of temperature has shown 1 deg. fahr. for each 60 to 64 feet descent toward the center of the earth.

The cooling and shrinking of the earth is still going on, which accounts to some extent for the earthquakes, volcanic eruptions and other minor changes taking place in the crust.

About eight-elevenths of the earth's surface is sunken below the rest and covered with salt water.

After the earth has become a cold body, too cold for habitation, it will appear as a bright moon to some other planet.

Geological Formation of the United States—The large fossil remains, found in Wyoming and the Black Hills of South Dakota, clearly prove that this section first appeared above the sea in this country.

The Gulf of Mexico extended up to the foot of the Rocky Mountains and the Black Hills on the northwest and to the Adirondack and Appalachian Mountains on the east and northeast. The northern shore of this original gulf extended westwardly from the Adirondack Mountains through western New York and Ontario. This period was ages before the formation of the Great Lakes, Niagara Falls and the Niagara River.

As the old gulf receded toward the present gulf, it receded in the form of a large bay, which accounts for the 45 deg. line in the State of Pennsylvania which the oil men of that state so successfully followed in their operations for oil.

The Ozark Mountains were an island thrown up in this large arm of the ocean by the shrinking of the earth's crust. The tendency of this upheaval was to divide the gulf into two smaller arms or elongated bays.

Following the formation of the different rocks, the earth was so hot at the equator that life could not exist, and at the poles the temperature corresponded very much to the tropical temperature of the present day. This statement is borne out by the finding of petrified animal remains and tropical plants in the arctic regions. As the earth cooled at the poles it kept driving animal life toward the equator and the time will come when even the equator will be so cold that life cannot exist.

Relative Location of the Large Gas Areas to the Old Gulf—The present Pennsylvania, West Virginia and Ohio gas fields are located on what was the eastern shore of the old gulf. The New York and Ontario fields were located on the northern shore, and the mid-continent field is located on the eastern shore of the peninsula formed by the upheaval of the Ozark Mountains in the center of the old gulf.

Origin of Natural Gas and Oil—The lowest order of animal life came into existence with the formation of the

Potsdam and Trenton rocks, and the source or origin of natural gas and oil must be attributed to the burying and subsequent decay of these mussels and other invertebrates.

During this age there were periods of storm and calm on the globe. When the sea was smooth, the sand was laid down loosely and when it became disturbed the sands were filled with either silicate or lime and cemented together.

In the first case, the spaces between the little pebbles became reservoirs for gas or oil generated by decayed animal life, while in the second case, when the sand was cemented, there was no room for such lodgment for either gas or oil.

Extreme storms during this period laid down what is called the "shell," which was thoroughly cemented, and which held down the gas or oil until the ingenuity of mankind drilled through it.

Oil is a product of natural gas caused by the pressure and confinement of the gases in the rocks, which are laid down like shingles on a roof. There is no such thing as a gas vein but there is a gas reservoir.

Though natural gas has its origin or source in the Potsdam and Trenton rocks, it may have to travel many miles to find an opening into an upper stratum.

Coal and gas or oil have absolutely no connection with each other, as gas and oil were in existence millions of years before the coal measures were laid down. For illustration—the gas of Alden, New York, coming from the Medina sandstone and free from petroleum, is smokeless. If the coal measures ever existed in this locality they would have been a mile and a half in the air.

Shale was originally soft clay.

Rarely can surface indications of either oil or gas be relied upon."

Fig. 1—PHOTOGRAPH OF A NEW OIL FIELD IN CALIFORNIA TAKEN FROM AN AEROPLANE.

VOLCANIC ORIGIN OF NATURAL GAS AND OIL

By EUGENE COSTE, E. M., Toronto, Ont.

In the following article on the Volcanic Origin of Natural Gas and Oil, the writer has endeavored to reprint the most essential paragraphs from the paper written by Eugene Coste, E. M., and published by the Canadian Mining Institute. Vol. VI., pp. 73 to 123, 1903.

"Science has long ago recorded and is recording every day in the newly developed oil and gas fields many facts which in my opinion have thrown and continue to throw the clearest light on the origin of the hydrocarbons, whether they be petroleum, natural gas, or solid hydrocarbons.

(A). As everyone knows carbon is the fundamental element of the organic world, but this must not blind us to the fact that carbon is also a very important element of the mineral world. Indeed the predominance of carbon in the organic world is one of the strongest evidences that can possibly be adduced to demonstrate its great importance, during past as well as present ages, in the mineral world (including of course the atmosphere) for vegetables and animals alike had evidently no other source to draw from. When one reflects on all the carbon subtracted from the mineral world during the past geological ages by all the representatives of the organic kingdom, especially since the beginning of the Carboniferous, to form not only the coal beds, but the limestones, he must admit that the primitive atmosphere was very rich in carbon.

Therefore large quantities of this element must have been dissolved in the first fluid magma of the earth, and large quantities of it must still exist in the fluid magma of to-day under the crust of the earth.

To know and demonstrate in just what form the carbon is there, and how, from it, hydrocarbons were produced, are not essential geological points, and I will consider it quite

sufficient to recall that chemists of high standing in the scientific world, such as Berthelot and Mendeljeff, have long ago (in 1866 and 1877 respectively) suggested very probable forms such as carbides under which carbon could exist in the interior fluid magma, and probable re-actions under which hydrocarbon compounds could be generated. The present great daily production of the hydrocarbon acetylene by the simple action of water on carbide of calcium is very suggestive in that respect, and these considerations, together with the further one, now proved and admitted, that eruptive magmas are hydato-pyrogenic, namely, contain the more or less notable admixture of water necessary to suggested possible reactions in the formation of hydrocarbons, are sufficient in that respect. The vital point is to actually show the carbon and hydrocarbon in the igneous rocks, lavas and emanations proceeding from these internal fluid magmas. That, geology can do and has done, in a great many instances, at points widely distributed over the whole surface of the globe; and we will now pass in review a few of these instances, namely:

1st.—In the Archæan rocks we find carbon under the form of graphite in gneisses, in pegmatite dykes, in granites, gabbros and other rocks, the igneous origin of which is undeniable.

2nd.—In the crystals of igneous gneisses and of most granites and other eruptive rocks, gaseous and liquid inclusions are most abundantly found, and these are very often constituted by carbonic acid and hydrocarbons, and also often contain chloride of sodium in solution or in minute crystals.

3rd.—Petroleum, or semi-liquid or solid bitumens have often been noticed and cited by many observers as occurring in traps, basalts or other igneous rocks.

4th.—Volcanic rocks forming vertical necks and pipes across horizontal strata and containing carbon in the pure

form of diamonds are also well known to constitute in South Africa the deposits of these precious stones.

5th.—I now come to the hydrocarbons and carbonic acid in volcanic manifestations of to-day. Only a few years ago the civilized world was suddenly startled and horrified at the report that an explosion of Mount Pelée had wiped away in a few minutes the entire population of the City of St. Pierre, Martinique Island. From the accounts of the catastrophe then published, it is quite certain that a fearful blast or tornado of gases suddenly shot from the side of the volcano, asphyxiating and burning in a moment 30,000 people. Nothing else, I submit, but gas would carry death so suddenly to so many thousand people, inside and outside of their houses, over a whole city. That these gases were mostly sulphur gases and very inflammable gases (which could be mainly nothing else but hydrocarbons) has also been made quite clear by the accounts of the very few survivors.

We mentioned above that these inflammable gases must have been mainly hydrocarbons (probably mixed with hydrogen and sulphuretted hydrogen), and we draw the above inference from the fact that inflammable or combustible gases thus constituted have often been noticed and observed before in connection with many other volcanic eruptions by scientists of great repute, who were actually able to collect and analyse these gases. For instance, in the Vesuvian eruption in 1855 and 1856, it was observed by Charles Sainte Claire Deville and Leblanc that the lava as it cooled and hardened gave out successively vapors of hydrochloric acid, chlorides and sulphurous acid, then steam, and finally, carbon dioxide and combustible gases.

At Torre del Greco, on the sea shore opposite Vesuvius, during the eruption of this volcano of 1861, Mr. Charles Saint Claire Deville and Mr. Fouqué gathered and studied the gases from the eruptive lava which was then partly

flowing under the sea. The combustible gases from it were collected under water before they could oxidize, with the following results, namely:—

	From Fissures of the Lava on Land		From Fissures of the Lava Under the Sea			
			10 to 15 metres from land	40 to 50 metres from land	Ab't 100 metres from land	Ab't 200 metres from land
	Dec. 23	Jan. 1	Jan. 1	Dec. 18	Jan. 1	Jan. 1
Carbonic acid..	96.32	95.95	88.60	59.53	46.78	11.54
Hydrogen and Proto-Carbon	3.68	4.05	11.40	40.47	53.22	88.46

(B). I now pass to my second paragraph in which I propose to show that all the petroleum, natural gas and bituminous fields or deposits cannot be regarded as anything else but the products of solfataric volcanic emanations condensed and held in their passage upward, in the porous tanks of all ages of the crust of the earth from the Archæan rocks to the Quaternary, or in veins, fissures and seams in the case of solid bitumens. Nothing is so simple and therefore nothing so natural as this origin. It can be abundantly proven, and I will divide the data and proofs I propose to adduce for this under the following heads:—

1st.—Direct proofs and rock pressure of natural gas.

2nd.—Complete analogy of the products of the oil and gas fields with the products of solfataric volcanic action.

3rd.—Location of the oil and natural gas fields along faulted and fissured zones, each one presenting a few peculiarities of its own, similar to the systems of volcanoes and to the mountain chains of the globe.

4th.—The oil, natural gas and bitumens are never indigenous to the strata or formations in which they are found; their "sands" or other deposits are nothing more than natural rock tanks ranging in geology from the Archæan to the Quaternary, and these extraneous products must therefore come from below the Archæan.

5th.—Oil, gas and bitumens are stored products, in great abundance in certain localities, while neighboring localities often are entirely barren, exactly as volcanic products would be, and the strata among which they are found are so impervious that it forces one to the conclusion of a source, with powerful energy, directly below their fields.

1st.—To the direct proofs given above of solid, liquid and gaseous hydrocarbons in lavas or other igneous rocks, or in emanations clearly volcanic, can be added direct proofs of volcanicity from a few of the oil and gas fields, and these will serve as a link as it were between the volcanoes, on the one hand, and the oil and gas fields where the volcanic origin is not so plainly apparent, on the other.

In the newly discovered oil fields of Texas and Louisiana, and also in the California fields, we have many no less direct evidences of volcanism, though they do not appear to have been understood in their true light. These are, in Louisiana and Texas, the Salt Islands and the "Mounds" of the Coast Prairie, such as the famous Spindletop, near Beaumont, which are clearly nothing else but "suffionis" or "salses," hardly extinct yet, grouped along fractured lines and marking in that region the dying out of volcanicity, that is to say, the dying distant echo of that tremendous volcanic energy which, a little further south, in Mexico, Central America and in the islands and along the south coast of the Caribbean Sea, is to this day so powerfully active.

Abundant proofs of the above statement are to be found in Professor Robert T. Hill's paper, and to me these proofs

are so conclusive that you will pardon me if I again quote copiously:—

"In the generally monotonous monoclinal structure (of the Coast Prairie of the Gulf) there are a few wrinkles or small swells likely to escape the eye of even the trained observer, and yet of a character which may have an important bearing on the oil problem. These are the circular and oval mounds, already described, which were first recognized by Capt. Lucas. When he pointed out Spindletop Hill to me, my eyes could hardly detect it; for it rises by a gradual slope only ten feet above the surrounding prairie plains. I was still more incredulous when he insisted that this mound, only 200 acres in extent, was an uplifted dome. But Capt. Lucas said that I would be convinced of the uplift if I could see Damon's mound in Brazoria County. In August, 1901, I visited that place, and returned for a second look at Spindletop, and was convinced that, if these hills are not recent quaquaversal uplifts no other known hypothesis will explain them. Damon's mound is an elliptical hill, a mile or more in greater diameter, rising 90 feet above the surrounding level. * * The salt islands of Louisiana were described by Capt. Lucas in the Transactions of the American Institute of Mining Engineers before his discovery of oil at Beaumont. (1). These so-called islands, rising from 80 to 250 feet above the surrounding marshes of the Coast Prairie, are hills beneath layers of stratified clay and sand. They belong to the same group of topographic phenomena as Spindletop Hill at Beaumont. By sinking through the superstructure of sand and clay Capt. Lucas located the salt bodies, and determined their horizontal extent, developing also the important fact that, though limited in diameter, they were of great depth, that of Jefferson Island having been penetrated for 2,100 feet without reaching bottom. * * * * The bodies of salt discovered beneath the hills of the Coast Prairie are of remarkable size, thickness and purity, notably those of Louisiana, and one discovered within the past few months at Damon's mound which, for its lower 700 feet, is pure rock salt with occasional traces of oil. * * * * * * It was Capt. Lucas who discovered the relation between the sulphuretted hydrogen fumaroles, gas springs, and sulphur incrustations at the surface and the bodies of subterranean oil; and it was his belief in this association that led him to seek for oil on Spindletop Hill. * * * * The oil is closely associated with the mounds, occurring on their slopes or summits. * * * In some localities hot water has been struck below the oil. * * * In the original Lucas well, the oil

itself is hot. * * * It had a temperature of over 110 deg. fahr. The oil seems to occur not in any definite continuous stratum but in spots of many strata. Gas in immense quantities and frequently under such pressure as to wreck the wells, has been struck before reaching the oil. This has occurred several times at Spindletop, twice at Sour Lake, and once at Velasco, where the destructive effect was terrific. Sulphur and sulphuretted hydrogen gas occur in intimate association with the Beaumont oil. In fact, the oil itself is said to contain 1 to 2 per cent. of sulphur, and the fumes of sulphuretted hydrogen are strong in the vicinity of the wells. * * * * Underground bodies of sulphur associated with the oil by natural processes have been found in many localities. The Calcasieu section of Hilgard shows at 540 feet in depth solid sulphur rock similar to that encountered at 1,040 in the Beaumont well. At Damon's mound a bed of sulphur from 10 to 40 feet thick was encountered above the salt. Crystals of free sulphur also occur in the cap rock overlaying the Spindletop oil. Capt. Lucas found the sub-strata of the south-eastern part of Belle Isle, above and down to the rock salt, were heavily impregnated with petroleum. Several calcareous strata containing sulphur were also encountered. * * * * The wells at Damon's mound encountered small flows of oil at depths of from 400 to 600 feet."

In his last report on petroleum in the Mineral Resources of the United States, Mr. F. H. Oliphant confirms the true nature of these mounds, as here indicated, in this significant remark:

"The depth of the wells to the productive bed varies from 880 feet, about the centre of the elevation at Spindletop, to 1,190 feet near the edge of the productive area, indicating that the stratum holding the petroleum is in a general way conical, which condition seems to be verified by the deep wells, less than 500 feet from defined territory, failing to find any trace of the open cellular carbonate of lime and pure sulphur structure encountered on the mounds, at depths of over 2,000 to 2,500 feet. The thickess of the oil-bearing formation is placed by different drillers at from 20 to 75 feet. It is almost pure carbonate of lime with more or less combined sulphur as well as surrounding crystals of pure sulphur."

To the volcanic solfataric phase of phenomena these mounds, or rather as we see, real vertical chimneys, must

surely belong. How else could be explained their hot oil, their hot water, and especially their vertical chimney-like masses of sulphur, salt, limestone and dolomite, permeated and impregnated with natural gas, oil, and hydrogen sulphuret gas?

If we now transport ourselves from Texas to the Island of Trinidad, at the other end of the circle of oil and asphalt deposits, which, as it has been remarked, border the Gulf of Mexico and the Caribbean Sea, what do we find there? According to Clifford Richardson and to Edward W. Parker, of the United States Geological Survey,

> "The chief source of the supply (of asphaltum) is a lake of pitch filling the crater of an extinct volcano. This lake lies 138 feet above the sea level, and has an area of 114 acres. The supply is being partially renewed by a constant flow of soft pitch into the centre of the lake from a subterranean source."

The solfataric volcanic emanations at Trinidad are also abundantly attested by the many mineral springs on that island, by the strong thermal waters with borates, iodides and sulphur compounds intimately mixed as an emulsion with the bitumen of the pitch lake, by the gas issuing from the cracks in the bitumen, and by the indurated clays, burnt red shales and porcelanites to the southward of the lake.

Similarly, in California, through all the extensive oil fields of that country situated along the coast Range which has been only recently uplifted, the solfataric volcanic phenomena are most abundant to this day in connection with the oil deposits which are found in very disturbed and dislocated strata of the Cretaceous, Tertiary and Quaternary. Here, the shales, interstratified with the bituminous and oil sands, have become reddened and burnt or bleached to white shales, and changed to porcelanites by the solfataric vapors, and they have also been greatly calcified and salicified by the hot calcareous and silicious waters. Hot natural

gas and hot sulphuretted hydrogen emanations, as well as hot and boiling waters, issue yet from the hot ground in a number of places, as at the Calera Rancho, six miles west of Santa Barbara, where, on the ocean shore, an area of twenty acres has lately subsided some 25 feet, and from the hot ground of which heavy petroleum oil oozes out with sulphurous and other vapors and hot saline waters. Mr. A. S. Cooper, State Mineralogist of California, in a paper on "The Genesis of Petroleum and Asphaltum," devotes a great deal of space to these red burnt and white bleached shales as connected with the genesis of bitumen in California, but he attributes the evidences of heat and heated vapors and steam everywhere shown by them to chemical heat engendered in the shales themselves in some mysterious way, or generated in some even more mysterious way in the metamorphic rocks below the Cretaceous.

This "chemical heat," according to Mr. Cooper, distills the carbonaceous vegetable matter in the rocks and the resultant gas, oil and asphalt migrate upward into the Cretaceous, Tertiary and Quaternary rocks to fill there the gas and oil sands and to form the asphalt veins.

But why this "chemical heat" should have been so accommodating as to have waited until the Tertiary and Quaternary formations were deposited before metamorphosing and distilling the lower formations is not clearly explained.

There remains now one more direct proof of volcanicity in the oil and gas fields to which I desire to especially draw your attention. This proof is general and present in all the oil and gas fields, and therefore of primary importance in a consideration of the origin of oil and gas; I refer to what has been called the rock pressure of natural gas. This great force, which often has thrown out of a well high above the derrick an entire string of tools weighing thousands of pounds and which often gushes the oil and the pebbles of the oil

sands with terrific force hundreds of feet high in the air, cannot be explained in any other way than as a remnant or spark of the initial volcanic energy, the stupendous force of which in volcanoes has so often caused most tremendous explosions, appalling in their magnitude and effects, blowing out enormous craters and sometimes whirling out without warning, as from the mouth of a mammoth cannon, a destructive tornado of inflammable and irrespirable gases over a whole city, as in the recent memorable instance of St. Pierre, Martinique. In some of the oil and gas wells this pressure of the gas has registered as high as 1,525 lb. to the square inch, or over 100 ton to the square foot, but it is generally considerably less and ranges ordinarily between 200 lb. and 1,000 lb. in fresh fields when first struck, at depths of from 500 to 3,000 feet. It varies greatly in the different fields from wells of the same absolute depth, even though the two fields are not far distant, as for instance in the case cited by the late Professor Edward Orton, where a well in Oswego County, New York, only gave a pressure of 340 lb. to the square inch from a depth of 2,100 feet, at which the gas was struck in the Potsdam sandstone, while another well in Onondaga County, N. Y., the "Munroe" well, where the gas was struck in the Trenton limestone at 2,370 feet, gave a pressure of 1,525 lb. to the square inch. But, and this is a very significant fact, which indicates plainly the internal origin from below, in the same field when gas is found in different strata, as it very often is, the strongest pressure is always in the lower stratum, and the rate of decrease of that pressure from the lowest stratum to the upper ones is very irregular, evidently depending on the more or less open channels of communication between these strata which existed at the time of the solfataric volcanic activity under that field, channels which have now long ago been closed up as a rule. The other significant fact of the rock pressure of natural gas is that it is a continually decreasing

pressure from the time the gas is first used in a new field until finally it is all exhausted. This shows, without a doubt, that there is nothing now behind that pressure, no hydrostatic column or anything else; the gas possesses this energy *per se;* it is its own life, and it imparts it to the water, or to the oil sharing the sands with itself to make them flow violently at first. Before long however, this decreasing pressure becomes powerless and the oil has to be pumped. This would not be the case if a constant hydrostatic head was behind it; therefore, this fact alone is enough to condemn absolutely Professor Orton's and Professor White's theory of hydrostatic or artesian water pressure as an explanation of the rock pressure of natural gas. Paleozoic and gas rocks of North America are far from being porous enough to form permeable sheets arranged in basin form between impervious layers and with porous outcrops, and thus never fulfill all the conditions necessary to constitute artesian basins. These rocks, ranging in geology from the Potsdam all the way to the Pittsburgh sandstone, just above the Pittsburgh coal, have in many cases furnished in shale series irregular bodies of oil and gas sands, unconnected and without outcrop. In this case, how can any one seriously adduce an artesian water pressure to account for the rock pressure of the gas? Even the Trenton limestone, which is a thick continuous stratum with long outcrops to the north and forming a basin under Ontario, is far from being pervious enough and therefore lacks some of the conditions for an artesian basin as absolutely proven by a number of wells which were drilled right through the whole series down to the Archæan below, without finding water. At Collingwood, where the Trenton limestone outcrops under the town and under the Georgian Bay, a number of wells, drilled there, have found only sulphurous and saline waters in small quantities below 130 feet; and, three wells which were drilled under the mountain, fifteen

miles south of Collingwood, pierced the whole Trenton limestone, from 1,160 to 1,750 feet, without finding a drop of water, though the top of the Trenton in these wells, situated miles one from the other, was about 275 feet below the level of the Georgian Bay in each instance. Where is Professor Orton's artesian water column here? It is not found right where it should be on the track between Ohio and the outcrops of the Trenton. It is only fair to add here that Professor Orton himself, in his presidential address read before the Geological Society of America, December 28th, 1897, abandoned as untenable his theory of artesian water pressure as the source of the natural gas rock pressure. Yet, there is surely a cause for these great pressures going up sometimes as high as 100 atmospheres, recorded by natural gas. If it is not a volcanic energy, what is it? Svante Arhenius, the distinguished Swedish physicist, has figured out that the crust of the earth is solid down to about twenty-five miles, and that at this depth, where the temperature must be 1200 degrees C. and the pressure about 10,840 atmospheres, commences the fluid magma; also that, at the depth of about 186 miles, the temperature must, without doubt, exceed the critical temperature of all known substances, when therefore this fluid magma must pass to a gaseous magma subject to extremely high pressures. Here then, only twenty-five miles, at most, below the gas fields, is an adequate source for the natural gas pressures, and this is the only adequate source we can possibly find. We also know that light hydrocarbon or natural gas is emanated abundantly in all the volcanic regions from these interior masses. We have therefore below the crust, and there alone, the source of the natural gas and its strong energy and life, called rock pressure.

2nd.—Complete analogy of the products of the oil and gas fields with the products of the solfataric volcanic action.

It is well known, and our brief review in the first paragraph of this paper shows, that the great solfataric volcanic products are water, chloride salts, sulphur, sulphuretted hydrogen, carbonic acid and hydrocarbons with often an admixture of hydrogen, oxygen and nitrogen. That all oil and gas fields in every part of the world present the above products in a remarkably constant association, though of course, occasionally a few of them may be missing, is a fact so well known that it is unnecessary for us to do more than refer to it briefly. We have already seen, that in the case of the Texas and Louisiana fields this association, mainly of salt, sulphuretted hydrogen, sulphur, and hydrocarbons, is most pronounced. So it is clearly in the Lima oil fields, including the Canadian fields, and in the California fields.

But, even in the Appalachian fields of New York, Pennsylvania and West Virginia, where the oil is free from sulphur and the gas is generally free from sulphuretted hydrogen, it is not always so and sulphur waters are very often found in the wells of that region almost as generally as salt waters and constantly associated with the oil and gas. The occasional presence of sulphur in the oil and gas at a few places along the Appalachian belt, especially in New York State, where it is found in lower formations, confirms Dr. David T. Day's suggestion that, if as a rule the Pennsylvania oil and the Lima oil differ in their sulphur contents and color, it is probably due to a filtering process which the Pennsylvania oil has been able to undergo in its passage upward through Devonian and Carboniferous fine-grained shales and sandstones.

3rd.—Location of the oil and gas fields, and of the solid bitumens along faulted fissured zones, similar to the system of volcanoes, and to the mountain chains of the globe.

Few geologists are to be found to-day who do not admit at least a liquid sub-stratum under a solid crust for the constitution of our planet, be the centre of it gaseous, liquid

or solid; and who do not also recognize the cooling and shrinking of this interior fluid mass as the grand cause of volcanicity including not only all the direct volcanic phenomena but also all the dislocations, movements, faulting and fissuring of the crust of the earth, except possibly some local and minor displacements. The mountain chains, therefore, and the volcanoes stand out as the chief results of one profound cause, in which the entire central mass of the whole sphere is in operation. It is only natural then to find the mountain chains and volcanoes of the earth in such long straight lines marking the much faulted and fractured grand circle zones of least resistance cf that sphere. But, in the resulting effects on the earth's crust, of the pressures causing these great orogenic and volcanic dislocations, we must expect to find all degrees of intensity from the immense parallel folding, fracturing and faulting, so grandly illustrated in so many of the great systems of mountain chains, to numerous zones much less dislocated and fractured, generally parallel to the neighboring mountain range or to some main offshoot of it, and in some cases possibly hundreds of miles away from it, and marking the progressively dying out efforts and effects of that particular great orogenic revolution from the mountain chain outward. These minor fissured and fractured zones may be of such slight disturbances and fracturing that this fact may hardly appear, especially when the surface is largely drift covered. Yet, the pent-up gases and vapors of the interior may, during the active period or periods of these disturbances, have succeeded in forcing their way up along these zones to or near the surface. Even in North America, where so much deep drilling for oil and gas has so long ago taken place, several of these disturbed and fractured zones have only been indicated in the last few years in the drilling operations connected with new discoveries of oil and gas. Such was the case in the

North Western Ohio gas and oil fields as shown by the late Professor Edward Orton in these words:

"Up to a recent date it was not known that the underlying rocks failed to share the monotony of the surface, but the explorations of the last two years have revealed the surprising fact that the rocky floor of the Black Swamp of old time is characterized by far greater irregularity of structure and by far greater suddenness and steepness of dip than the strata of any other portion of Ohio. The entire floor of North Western Ohio, including the lake counties, as far east as Lorain County, is seen to lie in a disturbed and uneasy condition * * * The Findlay break is abrupt and well marked, and is indeed the most remarkable fact in the structural geology of Northern Ohio. The occurrence of petroleum and gas, but especially of the latter, in North Western Ohio has been found to be associated with greater irregularities of structure than are known elsewhere in the State, except in a single locality. It is in Findlay that the most marked disturbance occurs, and the great supplies of gas that are found there appear to be closely connected with this disturbance."

Mr. Robt. T. Hill, in his paper on the Beaumont oil fields, previously referred to, says:

"There is some evidence that the Coast Prairie overlap conceals a line of serious deformation, which may be a sharp fold, with an increased dip coastward, or a zone of faulting."

Concerning this same region, Mr. E. T. Dumble says:

"While the Coastal Plain is now just what its name implies, during Tertiary times, it was subjected to oscillations, accompanied by certain phenomena which marked the dying out of volcanism in this region."

In the theory which he formulates to explain "the oil phenomena" of the Texas mounds, Mr. Hill, suggests that artesian saline waters bring up the sulphur and oil along this indicated line of faulting in that region; I simply go a little further and claim that this line of faulting gave access to volcanic emanations bringing the water, salt, sulphur, oil and gas from the interior in the state of vapors and gases, which condensed more or less near the surface, some escaping,

in their gaseous state as the hydrogen sulphuret and the natural gas.

In the famous Appalachian oil and gas belt bordering and following the Appalachian Mountains from the eastern shore of Lake Ontario to Alabama, for the distance of 900 miles, the evidences of parallel folding, faulting and fracturing are most numerous, as shown in the reports and maps of the Pennsylvania, Ohio and West Virginia Surveys, and if so many anticlines, slopes, synclines and terraces have proven to be good oil and gas fields all through this vast extent of country, and from rocks ranging from the Potsdam sandstone to the Upper Productive Coal Measures, it is certainly not because these hydrocarbons have moved sideways to the anticlines (as we will see below they cannot do on account of the imperviousness of the strata) but because this region being, at certain geological periods, a dislocated and fractured zone, the hydrocarbons have then moved upward from below through these faults and fissures. This is plainly evidenced by the solid vertical core of hydrocarbon at the Ritchie Mine, Ritchie County, West Virginia, where a straight vertical fissure, 4 feet wide in the sandstone, but much smaller and more irregular in the shales, is completely filled with a mineral pitch or inspissated petroleum, called Grahamite by Wurtz, and first described by Professor Leslie in 1863, and lately fully reported on by George H. Eldridge, of the United States Geological Survey, who seems to admit, with Professor White, of the West Virginia Geological Survey, that the source of the Grahamite is the oil in the Cairo sand 1,300 feet down, but that does not explain the source of the oil in the Cairo sand which, we will see, can be traced to below the Archæan. Therefore, the Ritchie Mine Grahamite vein, though only badly defined when traversing the shales, must, nevertheless, have extended at one time to below the Archæan.

4th.—That gas, oil and bitumen are never indigenous to the strata in which they are found and are clearly secondary products is abundantly proven by the study of the different petroleum districts all over the world where the deposits are seen to form most irregular patches, pools and fields of porous rocks of all ages impregnated with the petroleums. Any porous reservoir of the entire sequence of the sedimentary formations, from the Quaternary down to the crystalline rocks, may be filled with the petroleums and even fissures in the crystalline rocks below all the sediments (near Newhall, Los Angeles County, California) are thus found filled with a very light oil, almost naphtha. In many of the fields the oil and gas are obtained in a number of different sands or reservoirs some of which are hundreds and thousands of feet lower than the upper one and in neighboring wells the oil and gas are often tapped at entirely different depths. All of which plainly demonstrate that the source of the petroleums is below the crystalline rocks.

5th.—Another and last proof which I want to adduce is that the petroleum and natural gas deposits are such locally separated and accidental accumulations, often in such very large quantities, that their source must be from the deep-seated volcanic reservoir directly beneath, which, alone, is abundant enough and was powerful enough to force such large quantities of hydrocarbons through most impervious strata during periods of volcanic activity under these fields.

In discussing the origin of petroleum and natural gas, the mistake has often been made to suppose and admit that certain "horizons," especially of shales, are entirely "bituminous" over very large areas and are to be found spreading out uninterrupted, like coal beds for instance, over wide regions. In fact, in most of the papers which I have read discussing this subject, some more or less extensive bituminous shale horizon, sometimes situated above strangely

enough, is always pointed at as the source of the oil; but that, of course, as I have already remarked, does not solve the question of origin—it only defers it and shirks it as it were. But furthermore, I submit, that the evidence to be gathered in all the oil and gas fields shows how localized and accidental the deposits of these products are and that in no case do they form widely and uniformly spread "sheets." Carbonaceous shales sometimes form such "sheets" but not bituminous shales. Hunt has long ago denied that the so-called bituminous shales "except in rare instances contain any petroleum or other form of bitumens." These two words "carbonaceous" and "bituminous" are very far from being synonymous, and this fact has too often been lost sight of. But even when shales are really bituminous (that is contain hydrocarbons) they contain these only in spots, as well illustrated in the oil-shale fields of Scotland, where, in the different quarries, different beds of shales occupying a series under the coal 3,000 feet thick, are worked, the same bed not being found rich or "impregnated with oil" in more than one or two localities.

We have seen above how well the mounds and salt islands of Texas and Louisiana illustrate this localization of oil and gas deposits in a few small spots, here and there, with extensive barren stretches of the same formations between; and that the abundance of the oil obtained from under little Spindletop at Beaumont is so remarkable that it entirely precludes the admission of an indigenous source from the sedimentary strata under or near this mound.

All other fields show the same spotted and local feature of impregnation in their petroleum deposits. Even in North Western Ohio and Indiana where the oil and gas stratum is a limestone and where, therefore, solfataric waters could partially dissolve and dolomitize this limestone, thus rendering it more porous and spreading the subsequent oil and gas deposits more than usual, yet even there the 300 million

barrels of oil and the enormous quantities of gas, which have been obtained in the last 18 years, have been produced from very limited areas in these States, though in many other counties of these and adjoining States the same fossiliferous stratum, viz., the Trenton limestone, has proven barren of hydrocarbons notwithstanding that the organic source (if such there was) would be available there just the same as in the neighboring oil fields, as well as many anticlinal domes and other varieties of flat structure which have been regarded as necessary and sufficient to the accumulations of oil and gas travelling through from fossil sources.

The Berea grit in Ohio affords another most striking example of the localization of oil and gas pools. Notwithstanding that it underlies most uniformly 50 counties of Ohio and 20,000 square miles and that it overlies the greatest shale formation of the entire State, viz., the Ohio shales, ranging in thickness from 300 to 2,000 feet, and that it is covered by some 400 feet of impervious shales, viz., the Berea and Cuyahoga shales, yet it is only productive of oil and gas at a few points. How is it that since, as Professor Orton said,

> "There is everywhere underlying the Berea grit an abundant source of oil"

(the shales) and that, since the impervious cover is mostly always there over this vast territory protecting a good, continuous, often porous, sandstone reservoir, that in point of fact, as Professor Orton also said:

> "There are but very few localities in these 20,000 square miles where any noteworthy value has thus far been obtained from the formation in the line of these coveted supplies, and but a single field of large production?"

A few more fields have been found in the Berea grit since the above was written, such as Corning, Scio and others, but yet, after very considerable drilling, not one per

cent. of the 20,000 square miles has been found productive; and, where it has been, as remarked also by Orton in the same report, an "abnormal structure or dislocation of the strata" was noticed, like at Macksburg. This indicates the fracturing of the strata necessary for the local impregnation of the Berea grit and other "sands" with oil and gas.

But where the localization of oil is most striking is in the famous oil field of the volcanic peninsula of Apscheron, near Baku, Russia, where from a small area of not over eight square miles a production of oil of over 900 million barrels has now been obtained.

The very local and accidental distribution of the oil and gas fields is very unlike what would be expected from deposits of organic origin, which, like the coal beds, would naturally spread out uninterrupted over wide regions. On the other hand, volcanic products are *a priori* found localized along the lines of volcanic activity and there in large quantities, while the neighboring localities or districts not subjected to this volcanic action are barren. If we now recall the well known geological fact that volcanic activity is, and has been during all geological ages, shifting and intermittent along the fractured zones of the earth crust, that is to say, while it manifested itself intermittently in a certain region during a certain period, in subsequent ages it died out and became entirely quiescent in that particular region to break out anew in other portions of the earth, then we will realize that natural gas and oil, though volcanic products, are to-day in most every field where they are found, stored products not now renewing themselves in the recesses of the earth. We will also thus understand why the rock pressure and quantity gradually decrease as we take these products out of their deposits. The volcanic activity which brought them there through faults and fissures, was active, as it always is, only for a time, and now that this activity has expired, these faults and fissures have closed up and the

volcanic force is unable to refill the reservoirs, just as it is in most mining regions of the earth where a similar volcanic energy was, at one time, the immediate cause of the filling of fissures, veins and lodes now long ago solidified with quartz and other vein-stones more or less mineralized.

(C).—Complete inadequacy of all organic theories of origin.

I have shown that volcanic emanations of hydrocarbons are a natural geological process of to-day, abundantly verified and witnessed in actual operation in volcanic eruptions and phenomena all over the world.

Can as much be said of any of the organic theories generally advanced to explain the origin of the hydrocarbons? Evidently not! None of the processes called on by these organic theories are to be witnessed in operation anywhere in nature to-day. The late Professor Edward Orton, a profound believer in and a strong defender of the organic origin of petroleum, acknowledged this point plainly when he said in his presidential address before the Geological Society of America:

"It is easy to see how the bituminous series may result from the destructive distillation of either vegetable or animal substances enclosed in the rocks, and wherever conditions can be shown that provide for such distillation we are not obliged to go further in our search. Destructive distillation can take effect in organic matter that has attained a permanent or stable condition in the rocks, like the carbonaceous matter of black shales or coal; but it seems improbable on many and obvious grounds that this can be the normal and orderly process of petroleum production. This production of petroleum must be in active operation in the world to-day; at least it seems highly improbable that a process coeval with the kingdoms of life, growing with their growth and strengthening with their strength, a process that was certainly in its highest activity throughout Tertiary time, leaving a most important record in the rocks of that age, should suddenly and completely disappear from the scene upon which it had wrought so long and upon which all other conditions appear to be substantially unchanged."

We have seen above how far from having disappeared from the scene is the volcanic process of petroleum production, but Professor Orton was only looking to find in nature a petroleum production process "coeval with the kingdoms of life," and that he could not find it simply because it does not and never did exist. To me this is most clearly proven by the simple consideration of the natural geological processes of decomposition of organic remains and of the conditions pertaining in the oil and gas fields.

1st.—It is quite certain that the decomposition of anima bodies, as taking place in nature to-day, and we may, no doubt, say during all ages, is so rapid that the decay or combustion is complete before the entombment in the sedimentary rocks of these animal bodies, preserved in any way, can possibly take place. This is no doubt why instances are so rarely cited in geology of partially decomposed and preserved remains of animal bodies being found; only most exceptional cases, such as a few remains preserved in the antiseptic waters of peat bogs or a few frozen remains of Elephas, are given; but these exceptions only confirm the rule which is, viz., when there is anything left at all it is the shell or bones or their moulds or casts and no trace of the body is to be found. The fact that a few shells are sometimes found full of petroleum is a conclusive proof that this oil is a subsequent infiltration into the shell, as in the case of silt, silica, pyrites, calcite and many other mineral filling shells, a modicum of oil is all each shell would contain if the petroleum originated from the body, and invariably, when petroleum is found in fossil shells, it is also found in the porous or seamed strata in which the shells are embedded, showing the infiltration and impregnation from without.

2nd.—It is also equally certain that there is only but one normal process of decomposition and preservation of vegetable organic matter in nature to-day and in ages past, and that is the decomposition of it into carbonaceous matter,

viz., peat, lignite and coal. This process is in active operation in the world to day, as it has always been, and it is the only normal process "coeval with the kingdoms of life" that geology teaches us. Not one single authentic instance can be adduced, from the actual normal processes of nature, of any decomposition of organic matter "primarily" into petroleum. How could it be? The same conditions of low temperatures and of all other factors entering in the normal decomposition of vegetable remains must give only the one result and cannot possibly give two different ones, especially in the same strata and at the same places, for oil sands and coal beds are often contiguous. If then we do not find carbonaceous matter in any quantity below the carboniferous period, as the A B C of geology teaches us that we do not, the simple reason of it is, as long ago admitted by geologists, that before that period, the favorable conditions for vegetable growth had not yet developed to any extent, and not that it was transformed into petroleum, as attested by the small quantity of carbonaceous matter found in the Devonian and Silurian strata, which are witness and proof that the one normal process of decomposition of vegetable matter into coal was then already going on.

Then, since animal organisms were never entombed in the rocks, and since vegetable life was quite insufficient before the Carboniferous Age, how can the organic theories of origin be adduced to explain all the oil and gas found below the Carboniferous, and that means all the enormous quantities of oil and gas of the Lower Silurian limestone of Ohio and Indiana, and it also means almost all of the very large quantities of oil and gas developed in the last 40 years along the Appalachian belt which has been found under the coal in the lower and Sub-Carboniferous and in the Devonian and Silurian; and, much more in other fields. The fact often cited by the numerous exponents of the organic theories, as in the above quotation of the late Professor Edward Orton,

that, by destructive distillation, petroleum and gas can be obtained from coal or carbonaceous matter, and also from fish oil, lard oil or linseed oil, etc., will not serve here at all, for not only there was too little to distill in the rocks prior to the Carboniferous, but, what little there was, was not distilled and is to be found there to-day, undistilled, as the Paleozoic oil rocks of the oil regions of North America have, without the shadow of a doubt, remained unaffected by metamorphic agencies, and have never been subjected to the heat necessary to effect this distillation of organic matter. Nor have the rocks of the Texas section, and yet we have seen that petroleum, gas and asphalt are found in them from the Ordovician to the Quaternary. This destructive distillation of carbonaceous matter (and, we repeat, there is no other organic matter entombed in the sedimentary rocks but carbonaceous matter) could not possibly take place without leaving a residue of coke and of ash, and not only these residues have never been found under the oil and gas fields, but we know for certain that they do not exist.

In fact, if this distillation had taken place, there would be no coal fields anywhere as they would all have been changed into coke-beds.

We see, therefore, to what absurd deductions we are led by the organic theories of the origin of petroleum, viz., 1st, Abundance of vegetable life before the Carboniferous; 2nd, No coal anywhere on the globe."

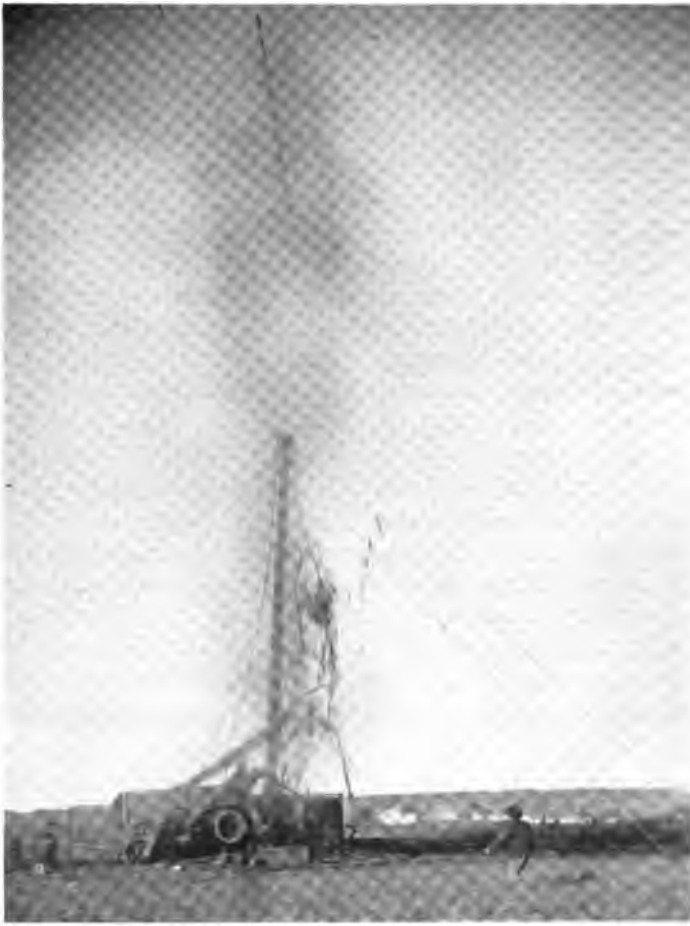


Fig. 2—INTERESTING PHOTOGRAPH OF THE STRIKING OF A LARGE VOLUME OF GAS IN KANSAS.

FORCE OR POWER OF NATURAL GAS.

The average natural gas man is so accustomed to opening a gas well into the atmosphere that he seldom realizes the tremendous power in the gas flowing from a large well. It merely is part of the business.

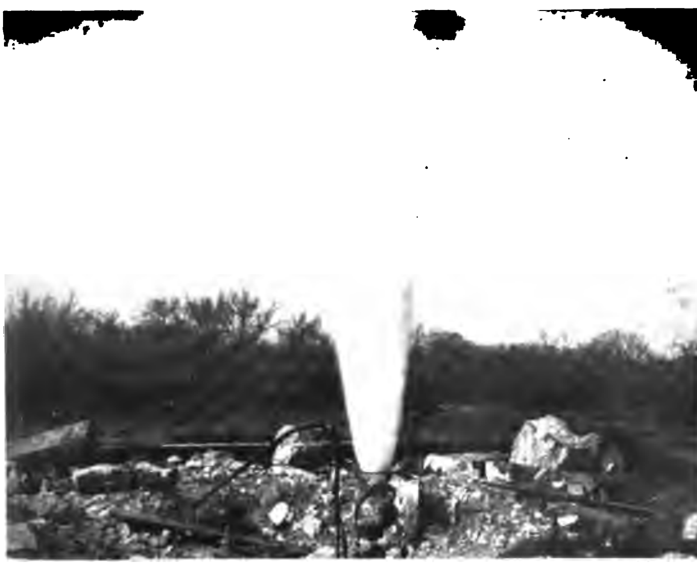


Fig. 3—GUFFEY NO. 4, AT WHITE POINT, TEXAS. FLOW, 30 MILLION CU. FT. PER DAY, AND 1200 LB. ROCK PRESSURE

Pipe lines are "blown up," gate valves and regulators are worn out till but a shell remains, and derricks are buried or disappear from sight. Yet the average gas man little realizes the tremendous power of natural gas. In the articles following the author has endeavored to convey an idea of the wonderful power of natural gas as it first issues from the earth.

Fig. 4—ACTUAL PHOTOGRAPH OF A STRING OF TOOLS WEIGHING OVER 4000 LB. BEING BLOWN FROM A WELL BY A LARGE VOLUME OF GAS.

The following article appeared in the *Fuel Oil Journal* under date of December, 1914.

TEXAS GAS WELL SWALLOWS DERRICK AND MACHINERY

After Blowing Out Drill-Stem and Casing it Develops a "Crater" 100 Feet in Diameter

"Corpus Christi, Texas, Nov. 27.—(Special.)—Experienced oil and gas men who have seen the White Point Oil & Gas Co.'s No. 2 well, near Corpus Christi, on the Gulf Coast, say it is the largest gasser ever drilled in Texas, and some who saw "Big Moses" in West Virginia, believe it was a larger well than "Big Moses." It has been variously estimated at from 40,000,000 to 50,000,000 cu. ft.

The well broke in on the drillers unexpectedly Wednesday morning, November 11. The crew had pulled out the night before to put on a new bit and was going back in the hole the next morning with 4-inch drill stem and had in 1500 ft. when the well blew out, tearing away the crown block and portions of the derrick and bringing out large boulders, pieces of shale and mud with a small quantity of water. The drill-stem was thrown several hundred feet in the air and the bottom of the pipe with the bit on it struck the ground 600 ft. from the hole, the balance of the stem being twisted and scattered around on the ground from 100 to 300 ft. from the rig.

The roar of the escaping gas could be heard plainly in Corpus Christi, seven miles distant, and the column of vapor could be seen five miles away. After blowing steadily for three days it choked for a couple of hours, then came back again, blowing out eight joints of 6-inch casing and opening up gas blowouts all along the water's edge in Nueces Bay at distances from 150 to 1000 ft. away from the well. This continued for a couple of days, when the formations on

top caved and the derrick, machinery and casing, several thousand dollars worth of material, went into the hole, the boiler being all that was saved. The hole is a total loss. The well continues to cave and is making quite a lot of water with the gas.

Fig. 6—HOW THE WHITE POINT GAS WELL LOOKED AFTER IT HAD SWALLOWED THE DERRICK AND MACHINERY. The "crater" is about 100 feet in diameter, and the water is thrown 25 or 30 feet in the air by the force of the gas which is coming up at a point a little to the right in the foreground.

Formed a Crater—It has formed a crater 100 ft. across and is steadily working toward the bluff, about 200 ft. distant. At the present rate it will soon cave to the water's edge and then pour into the bay.

At first the gas was odorless, but during the last few days a sulphur smell is noticeable. Some take this to indicate the presence of something under the rock and a possibility of blowing in oil. The main volume of gas continues to come from the center of the crater. Gas is escaping through

the water in numerous places along the bay, near the water's edge, and also 500 to 600 ft. out in the bay.

The well is the second one drilled by the White Point Oil & Gas Co. It is located on part of the Seguin survey, in San Patricio county, Texas, on the east side of Nueces Bay, about seven miles a little west of north of Corpus Christi and 10 miles south of Sinton. It is on a 50-ft. bluff which follows around Nueces Bay on the east side for a distance of several miles. Gas is in evidence along the water's edge a mile along this bluff in each direction from the present well. Limestone outcroppings are in evidence all along the bluff.

Old Well Started Blowing—The well is 1000 ft. south of the first test, which was drilled to a depth of over 1900 ft., and which made considerable gas, furnishing enough to drill the big gasser. The new well was cased with 1935 ft. of 6-inch, rock being found at 2165 ft. The drill had penetrated the rock 95 ft. when the well blew out. Several strata of rock were penetrated. None was found in the first test. An old hole, known as the Hager well, which was drilled by the J. M. Guffey Petroleum Co., several years ago to 1200 ft., is one corner of a triangle formed by the three wells, being about half-way between the White Point Co.'s Nos. 1 and 2. It also blew out when the 6-inch was blown from the new hole and it continues to gas."

Fig. 6—CRATER MADE BY THE CLARKSON WELL AT WHITE POINT, TEXAS

INTERESTING EXPERIENCES WITH WHITE POINT GAS WELLS.

The following article was received in a letter from E. C. Kincaid, of Houston, Tex., and describes some interesting experiences with the White Point gas wells.

"Our Well No. 2 was drilled to 3,129 feet when it unexpectedly came in. The writer had a very funny experience with this well: Our man called up from White Point and asked us to send him a Pitot Tube to take the pressure, and said the gas was flowing very strongly. I could not find a mercury gauge, but sent him a thirty-pound pressure gauge. We made him up a very good gauge with 1/8" iron pipe and finished it very nicely. When he stuck the pipe into the gas, he came back and reported that the gauge would not move, that he had to drill a hole through a board and stick the pipe through it and have two men hold the end of the pipe into the gas on account of the great velocity. He was advised to try the boiler gauge and then the pressure on this went to 110 lb. open flow through an 8-inch collar. It was later found that the thirty-pound gauge hand went around and was standing against the pin. If I remember correctly, we calculated this well at 115,000,000 cubic feet. Our superintendent of production then had some contrivances made at our Beaumont machine shop and capped this well, using an extra heavy gate and heavy pipe and a Bell nipple, or practically the same kind of connections that you have seen on copper tubing. He first prepared a foundation around the well by pouring in something like eighty-five yards of concrete around the casing and putting in four 2-inch anchor bolts. Of course, he allowed the gas to blow through the gate while getting this in place, but in about two hours after he had shut this well in, the 2-inch bolts were stripped out and the well blowed then for about 48 hours, making gas, sand and stones. The 8-inch and 10-inch casing came out in pieces as thin as stove pipe, and the craters were formed in about 48 hours after this, being probably 150 feet in diameter and 50 feet deep. This crater is now nearly 250 feet in diameter and about 100 feet deep.

There was a peculiar condition in connection with this well. After the crater had been formed and the gas was still flowing, it made some salt water and would set itself on fire and then would smother itself out. It is very hard to explain just what the phenomena was, because the fire would evidently go out with as much gas blowing as was ordinarily coming out of the hole. There was

Fig. 7—CRATER MADE BY THE GUFFEY No. 2 AT WHITE POINT, TEXAS. THE DIAMETER IS 300 FEET AND THE DEPTH ABOUT 150 FEET

not enough dust or salt water either to smother the flame, but it would simply burn out as if it lacked sufficient air. I thought probably at the time it was the CO_2 in connection with the salt water and sand that smothered the flames, but after blowing for twenty or thirty minutes without any fire, it would suddenly ignite, and the peculiar part—the ignition would appear to be on the outer edges of the gas itself. The only way we could explain this was, that the heated rocks were striking and making sparks. It might be interesting to know that there was often accompanying the ignition in the air a slight explosion. I absolutely saw this well ignite and go out over a half-dozen times, while the men on the ground say that this occurred probably a hundred times before the gas quit flowing.'

Fig. 8—STEEL STEM THROWN OUT OF A GAS WELL 3276 FEET DEEP IN THE BLACKWELL FIELD, OKLA.

GAS VOLUME

It is seldom possible to ascertain the volume of gas that has issued from a given gas field, but the author is familiar with one portion of the Mid-Continent field concerning which accurate data relative to the acreage, the thickness of the sand, and the volume of gas taken therefrom was obtained. The company operating there has permitted the publication of this data, provided the name and location of the field are withheld. The following chart and information, refer to this field.

Fig. 9—VIEW OF A "CRATER" WALL AT WHITE POINT, TEXAS

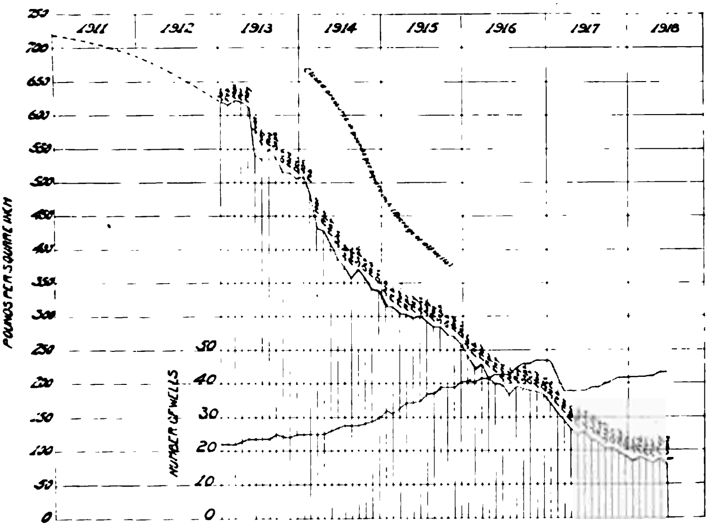


Fig 10—CHART SHOWING THE ROCK PRESSURE AND THE NUMBER OF WELLS FROM YEAR TO YEAR, IN THE FIELD DESCRIBED ON PAGE 39.
Note the declining rock pressure.

1.—"The length of this field is approximately five miles by two and one-half miles in width, and covers an area of about 6,000 acres, running in a Northwest-Southeast direction.

2.—The rock pressure of the first wells was 740 pounds.

3.—The average thickness of the sand is 25 feet, but it varies from 2 feet to 30 feet. The sands are found at from 1500 feet to 1860 feet.

4.—From the best information obtainable, we estimate that there has been something over one hundred billion (100,000,000,000) cubic feet of gas taken from the field."

The foregoing facts will serve to show the possibilities of the existence of a great volume of gas in a limited area under the crust of the earth. This particular field is still

furnishing gas, and while the rock pressure is low it bids fair to continue to be a valuable field for many years to come.

The foregoing information might lead one to believe in the volcanic origin of natural gas. Whether it does or does not, it establishes beyond a doubt the existence of large volumes of gas in small areas under the crust of the earth.

RELATION OF NATURAL GAS TO THE CRACKS AND CANYONS OF ARIZONA

During the spring of 1919 the author took a hunting trip to Sycamore Canyon some twenty miles south of Williams, Arizona, or approximately one hundred miles south of Grand Canyon, having no thought in mind of the geology of the country. The first few days were spent on the East side of canyon and the remainder of the trip was at the head of the canyon, hunting around the rim and adjacent territory for a distance of thirty miles. In all we probably traveled two hundred miles during the trip in the country surrounding the canyon.

Before reaching our camp on the first day out it was noticed that this practically level country was covered with loose rocks, the majority of which ranged in weight from a few ounces to a few pounds and in certain sections reached a weight of several tons. Very few of the smaller rocks were embedded deep in the soil.

There were a few "dry land" farmers working within a couple of miles of the canyon. In clearing their land they remove the rocks from the surface and pile them along the fence line, after which they proceed with their plowing without hindrance from any rocks under the surface. Along all fence lines surrounding cultivated land in that vicinity, is a row of loose rocks as above described.

The country is covered with a heavy growth of pine and can not be considered a "broken up" country such as

Fig. 11—VIEW ACROSS THE LARGE CRATER.
Note the Pine Tree over One Hundred Years Old, also the Guide standing on the Rim of the Crater.

Fig. 12—BOTTOM OF LARGE CRATER SHOWING BROKEN ROCKS.

Fig. 13—Piece of Porous Red Rock picked up one mile from the Rim of the Canyon. (One-half Size).

is found in many oil and gas fields, except at the canyon. In approaching the canyon through the timber one hardly realizes that a canyon is near until within a couple of hundred feet of it.

The canyon is from nearly one thousand feet deep at the head to over three thousand feet deep some ten miles below. It runs nearly due north and south with many small branches laid out somewhat l.ke veins of a leaf. The altitude of the rim is about 6500 feet. A large part of Arizona is a plateau of from 6000 to 8000 feet in altitude, which no doubt was formed by the shrinking of the earth's crust.

One of the most significant facts about Sycamore Canyon is that there is no flowing river nor ever was any river of any size in the bottom of the canyon. There is a creek bed in the canyon which is dry except after heavy storms. Even during heavy storms there is very little water running in it. There are a few springs located throughout the canyon but the water from them is soon lost in the ground. It was very evident that this canyon was not formed by erosion.

The geological formations of the canyon are the same as at Grand Canyon except there are not as great a variety due to the fact that the canyon is not as deep. The Kaibab Limestone is near the surface and Supai Red Beds are near

the bottom of the canyon. The former is greyish in color and the latter is red, similar to the Red Medina of New York State.

Many of the loose rocks found in the country surrounding the rim were from the Supai Red Beds and were porous, as shown in Fig. No. 13.

In all our travels we did not find any trace of lava. There were no craters of that character found.

Near Weeping Willow Spring, which is at the head of the canyon, there is a small "crater"* or hole in the earth. This "crater," as the guide termed it, is about 225 feet in diameter., forming a perfect circle and probably 125 feet deep. It is located close to the rim of the canyon with only about 20 feet of rock intervening at its narrowest point. The top of this is on a level with the surrounding country. The high, narrow wall-like piece between the rim and the crater is cracked and shattered near the top but only for a short distance below.

This crater is fully illustrated in Fig. No. 11 to 15. From appearances, the rock around the rim would topple in toward the center as though it were undermined and then would be blown out from the crater by a powerful force. In Fig. No. 14, the picture is taken looking west and in Fig. No. 15 it is taken from the same point but looking east. If one will study these pictures, one will notice the large masses of rock breaking away from the rim and ready to fall into the crater. Fig. No. 12 will illustrate the character of the bottom of the crater, which is covered with loose rocks and very little grass or weeds.

Another but smaller crater was found about one mile to the south on the west side of the canyon. This, like the large crater, is located within twenty feet of the rim of the canyon. It is about one hundred feet in diameter and

*Crater is associated with the word volcano, but in this article the word is applied to the holes around the rim of the canyons.

some fifty to sixty feet deep. The character of the sides and the bottom is the same as the large crater previously described.

No craters were found other than those located close to the rim. That these craters were formed by erosion would

Fig. 14—LOOKING WEST ALONG RIM OF LARGE CRATER
Notice the mass of rock falling toward the center of the crater in both this picture and in Fig. 15.

be impossible or that they were of volcanic origin is out of the question, as no lava was found. No doubt they were formed in the same manner as the canyon itself, but were separated from it by some peculiarity in the rock formation near the surface. At the head of one of the branches on

the East side of Sycamore Canyon the geological formation is very interesting. The branch itself narrowed down to some thirty feet across at the extreme head and is formed by perpendicular rock at least two hundred feet high. The rock surface is exposed back from the rim for a distance of

Fig. 15—LOOKING EAST ALONG THE RIM OF THE LARGE CRATER. Both this and picture shown in Fig. 14 were taken from the same point.

one hundred feet and during a severe rainfall served as a creek bed. This rock is cracked for at least fifty feet back as though the cracks were a continuation of the branch canyon, and they also extended down the perpendicular face of the wall to the bottom of the canyon.

Fig. 16—CRACK IN THE EARTH'S SURFACE. AT THIS POINT THE CRACK IS ALMOST TWO THOUSAND FEET DEEP

The larger canyon and all its branches have the appearance of having been formed by erosion, *i, e.* by a flowing river. This effect could easily have been caused by rainfall, frost, and wind.

In this section of Arizona the climate is somewhat like that of Indiana or Illinois. Snow and cold weather are not uncommon in winter.

It would not require many years of exposure to the elements to create the erosive effects on the walls of the canyon such as are found in any of the canyons of Arizona.

There is very little doubt but that this canyon is of later origin than the Grand Canyon.

The author has never hunted or travelled around the Grand Canyon except for a day on Bright Angell Trail, consequently, can only repeat information obtained from the guide, who had travelled or hunted for years on both the south and the north rim of the canyon He stated that there were many "craters" on the north side of Grand Canyon similar to the ones described around Sycamore Canyon, except that they were larger in diameter and deeper and that the bottom of them was entirely covered with grass. He also stated that the country surrounding the South rim of the canyon was covered with loose rocks similar to the country around Sycamore Canyon.

In talking with a ranchman who formerly lived south of Winslow, Arizona, some interesting information was obtained about cracks in the earth's surface, near his former home. The author has carefully investigated this and found it of more than ordinary interest in connection with the above article regarding Sycamore Canyon.

South of Winslow, Arizona, there exists a series of cracks in the earth's surface ranging from a few inches to eight or ten feet in width and extending from thirty to forty miles in length. Their depth varies from a few hundred feet to an unknown depth. One can drop a stone down and hear

Fig. 17—ONE OF THE CRACKS OF ARIZONA

it hit first one side then the other as long as it is possible to hear a sound. A stone was dropped down the crack shown in Fig. No. 16 by the photographer and it required nineteen seconds before it struck bottom or a ledge. Occasionally people and animals fall into these cracks and are never found nor heard from again.

At the request of the author, Mr. O. D. Horton visited the cracks south of Winslow, and his description is given in the following paragraphs:—

"The first cracks we reached were 15 miles southwest of Winslow. We measured the depth of these cracks and found them to vary greatly. The first place we measured was about 42 feet deep. We followed this crack for a distance of about ¾ of a mile, making tests as to depth at several places. These soundings showed depths of from 25 feet up, in one place running as high as 1,965 feet, this being the greatest depth which we found. The width of this crack varied from 6 or 8 inches up to 10 or 12 feet. We found the greatest part of the distance followed by us was either completely covered or nearly covered by the sand washing into the cracks with the weeds and filling same until the cracks have disappeared. The cracks, however, could be followed and a distinct line noted nearly all the way.

For the first few feet at the top, the crack was the widest. From there it narrowed down until the main portion of the crack was only 6 to 12 inches in width. The walls of the crack were very irregular so that when taking soundings we sometimes experienced great difficulty in withdrawing our weights; the weight becoming lodged in the narrow places, would stick, and several times we lost the weight and had to take new soundings. In a few places a man could climb down into the crack for a distance of 25 or 30 feet. An examination at about this depth showed the rock to be of a brown or reddish sandstone, crumbling very easily, which undoubtedly causes a great deal of the filling. There seemed to be considerable shelving in this section, making the soundings very difficult to obtain, due to our weight resting on these shelves and the difficulty of swinging off into the crack.

To the east of the first cracks visited, we found another series, which is undoubtedly a continuation of the first series. These cracks are, at the present time, very shallow, being only from 15 to

Fig. 18—A CRACK SHOWING CAVING ROCK AT THE SURFACE

25 feet in depth, but this is due to the fact that they are more or less filled with sand and rocks washed in during the rainy season. Parties who live in this section say that after a hard, washing rain, these cracks will become very deep again, possibly 400 to 500 feet. The cracks in this section were wider at the top than the ones previously examined, in some places being 40 to 50 feet in width. We crossed one place about 200 feet in width and on either side the evidence showed that it was a continuation of the crack which had become filled with the sand and earth until the crack itself had disappeared and it had become level with the surrounding country.

The rock formation in this section is of a hard, white limestone, and a very light sandstone intermingled. The rocks are breaking off and gradually falling into the cracks which accounts to some extent for the increased width of the cracks in this section. The rocky sides contain transverse and lateral cracks which run in all directions."

The most plausible theory of the formation of Sycamore Canyon is that it was formed by the cracking of the earth's surface, due to the cooling and shrinking process that is constantly going on in the earth's crust and that the crack extended through to a strata of rock holding a large volume of natural gas under extremely high pressure. The releasing of the natural gas under high pressure broke up the rock and threw it out on to the surrounding country.

The duration of time of this great blow-out is of course problematical. We do know that at White Point, Texas, the Gulf Production Company drilled a 100 million gas well in 1915 and before it could be capped, it blew out and made a "crater" or hole in the earth of tremendous size over night. In this case the formations were Tertiary which caved in and together with the water in the soft formations quickly killed the well. The gas came from a drilled hole but a few inches in diameter. This interesting blow-out and crater are carefully described in pages 37 to 39.

The author has cited this "blow" to impress the readers the great force that natural gas has when under high pressure.

To return to the cracks and canyons—

Fig. 19—CRACK IN EARTH'S SURFACE SOUTH OF WINSLOW, ARIZ.

Sycamore Canyon is not sufficiently long to receive enough drainage to form a river in its bottom, yet deep enough to compare with Grand Canyon. Sycamore Canyon is from 20 to 30 miles in length, while Grand Canyon is several hundred miles long. If a canyon were opened up of any great length such a Grand Canyon it would naturally follow that the drainage of the country adjacent to the canyon would flow into it and if the canyon extended a sufficient distance it might receive enough drainage to either create a lake or a river. Is it not possible that a canyon would be formed first and the river afterward, instead of *vice versa*, as geologists believe? No doubt after a canyon is formed by a gas blowout and a river created, the river would have its effect on the canyon, *i. e.* deepening it, changing its general structure in the bottom and increasing the width.

Arizona might be called the Canyon State, likewise, it is the only section of the country in which cracks of any size and depth exist. It has the greatest plateau in the country.

In reading this suggested theory it no doubt will occur to the reader that to create a canyon of the size described, namely Sycamore Canyon, would require a tremendous volume of gas in addition to an extremely high pressure. To best illustrate how this could be possible, a few figures concerning a small gas field in the Mid-Continent section are given on pages 39 to 42.

A hundred years from now a stranger on visiting the "craters" of White Point, Texas, might after thoughtful consideration come to the conclusion that they were caused by erosion.

Fig. 20—GRAND CANYON FROM MOHAVE POINT WITH COLORADO RIVER SHOWN IN THE DISTANCE

THE RAPID EXHAUSTION OF OHIO'S NATURAL GAS RESOURCES, AND THE BEST PLAN FOR CONSERVING THE REMAINDER.

By

I. C. WHITE,

State Geologist of West Virginia.

Ohio, like her sister States of West Virginia, Kentucky, Indiana, Michigan and others, was carved from Virginia, the fruitful mother not only of Presidents but of many States as well. Three of these States, Ohio, West Virginia, and Kentucky, together with western Pennsylvania, and the western border of Virginia, cover the main body of the great Appalachian basin, the richest depository of mineral fuels yet discovered anywhere on the earth. To boundless stores of coal or solid fuel in almost every variety, in this richest coal field of the world, provident Nature has added vast deposits of liquid fuel or petroleum of the purest and most valuable type, together with the largest and most productive natural gas fields of the continent, so that eastern Ohio occupying the northwestern border of this great Appalachian basin has received a fair share of its wonderful fuel deposits of every type. How have your citizens administered this rich heritage? I fear the answer is something of which you are not proud, to say the least, that in fact the record of waste in coal, and natural gas especially, has been nearly, if not quite as bad as in my own state of West Virginia, and in practically every other State of the Union. The writer well remembers when one of your very large gassers, the great Karg well of the Findlay region, burned into the air both day and night for several years at the rate of 30 to 35 million feet of precious natural gas daily, just like the large Murraysville gasser and others of western Pennsylvania, and the Warfield well of the Kentucky-West Wirginia border, had continued their inglorious careers of waste at practically the

same rate as the famous Karg well for many years before the drill discovered the latter in its rocky home within the Trenton Limestone. On account of this period of reckless fuel waste, through which every State where natural gas exists seems destined to pass, the rich original fuel resources of Ohio are rapidly disappearing. Her coal beds by wasteful mining methods through which frequently 30 to 50 per cent of the coal in each seam is left in the ground, are being so rapidly exhausted that only 50 years hence will see the end of the coal mining industry in Ohio, except from very thin beds at great depths below the surface. With modern mining methods a recovery of 90 and often 95 per cent of the available coal is frequently accomplished, while 20 per cent should be the maximum of loss under any conditions. The writer is credibly informed, however, that in the mining of one of your most valuable coals, the No. 8 seam or great Pittsburgh bed, especially in Belmont, Harrison and Jefferson counties of your Commonwealth, that anywhere from 30 to 50 per cent of this most valuable bed is lost beyond recovery through wasteful, and primitive methods, just like it is in many of the mines of the same coal across the Ohio River in the Moundsville, Marshall County, region of my own State of West Virginia. With only a 50 year's supply of coal in sight for your coal mining business and the other vast industries of your prosperous State, so dependent for successful operation upon cheap fuel, it would seem the part of wisdom that this large and unnecessary waste of your precious coal deposits should speedily end.

Ohio, while not so richly endowed with natural gas deposits as was West Virginia, yet originally contained an enormous quantity of this priceless fuel, having two splendid gaseous and petroliferous reservoir horizons lying much lower in the geologic column than any yet drilled to in West Virginia, although this sister State has two of the deepest wells in the world. One, the M. O. Goff, 8 miles northwest of

Clarksburg, Harrison County, No. 4190 of the Hope Natural Gas Company, which under the brilliant administration of Mr. John G. Pew (now President of the Sun Company), attained a depth of 7,386 feet, and even at that enormous depth had only passed 37 feet into the Corniferous or Columbus Limestone which crops to the surface here in your splendid city. Hence even at the bottom of the Goff well, the drill was still 1,000 to 1,200 feet above the famous Clinton Sand gas horizon of Ohio. The other (the I. H. Lake) and still deeper well is located in the adjoining County of Marion, 6½ miles southeast from Fairmont, drilled by the same great gas company, but under the administration of Mr. Pew's very able lieutenant, John B. Corrin, who after the former retired from the Hope Company, concluded to go his former chief one better, even though Mr. Pew had beaten the German deep well record, the Czuchow boring which had proudly bid difiance to all for many years at a depth of 7,349 feet, and therefore when the story of the I. H. Lake Well, No. 4304 of the Hope series, had been closed, the drill rested in its stony prison at a depth of 7,579 feet, 193 feet deeper than Mr. Pew's best record, and 230 feet deeper than the German boring which had held the pennant for so many years. Hence, should Mr. Corrin ever retire from the Hope Company, and his friends and admirers (of whom, like Mr. Pew he has a host) should tender him a farewell banquet, he will be entitled to have his photo also framed in crystal bearing the picture of a derrick alongside as a souvenir appropriately inscribed with the legend, "The deepest well in the world". This well, although starting about 600 feet geologically below the Goff, did not reach your "Clinton Sand," since it had only passed 611 feet below the top of the Columbus or Corniferous Limestone when the caving shales from over a mile of unlined hole caught the drill in their stony embrace, which (like Ginevra of old) got "fastened down forever", still 600 feet or more

above the coveted Clinton gas horizon, and probably 1800 feet above the deeper Trenton gas and oil zone of Ohio's Lima and Findlay regions. Therefore while northern West Virginia holds several producing sands in the Upper Devonian measures between the Berea Grit and the Corniferous Limestone that do not seem to occur at all in Ohio, having thinned entirely away westward, yet the main gas producing zone of Ohio, the Clinton Sand of the Silurian, and the still lower Trenton Sand of the Cambrian, are not yet among our West Virginia proven gas reservoirs.

From recent studies of the natural gas resources of my native State, it has been estimated that at least three-fourths of the original supply has been exhausted, of which very probably much more than one-half has gone into the air unused for any purpose, and it is quite probable that Ohio's original supply is exhausted to about the same extent with a waste nearly as great as that in West Virginia.

It was the writer's good fortune to have had an intimate personal acquaintance with the late Dr. Edward Orton, State Geologist of Ohio, for many years. Dr. Orton was not only one of the most eminent geologists of the period in which he lived, but a ripe scholar, able and philosophic thinker, a brilliant writer and one of the most gifted teachers your great State has ever produced. Dr. Orton's special study of oil and natural gas began about the time of my own in the latter '70s and he always insisted to the day of his lamented death that natural gas was a fuel too pure and refined to use for general manufacturing or power purposes where coal is accessible, and that it should have been conserved entirely for domestic fuel, which but for the frightful waste and unwise use would have lasted for centuries instead of decades within the areas now supplied. The truth of Dr. Orton's far-seeing vision, in which the writer always concurred, is just now being adequately realized by the great producers and suppliers of this most wonderful fuel which

Dame Nature furnishes from her laboratory already manufactured, purified, ready to serve the domestic user with light, heat or power in double the value of any other gaseous fuel that man has ever been able to generate.

The producer and marketer of natural gas has never asked or received an adequate or equitable price for his commodity, either for domestic or manufacturing purposes. This statement should be self-evident to anyone who will give serious thought to the question. First, let us consider the cost of gaseous fuels manufactured in retorts either for light, heat or power. In your sister city of Wheeling, just south of the Ohio border, municipal ownership of public utilities has enjoyed one of its earliest tryouts in the city gas works. Manufactured gas containing approximately 550 B. T. U. was once sold by the City of Wheeling to its citizens at a price lower than in any other municipality of this country, since, while the people in other cities were paying from $1.50 to $2.50 per 1000 cubic feet for manufactured gas, Wheeling was selling the same to its citizens for only 75 cents. This result was long pointed to as a conspicuous example of the economic results and benefits flowing from municipal ownerships of public utilities. Wheeling still owns her gas works but they have ceased to function and are at present being junked. Her citizens are now liquidating the former benefits they enjoyed at probably much less than actual cost. It may be set down as an axiom that if the people of any municipality receive the services of any public utility at less than cost or at less than a fair profit, they will later either directly or indirectly be compelled by inexorable economic law as unchangeable as fate itself, to make up the deficit and often much more. This homely truth is just now receiving a nation-wide illustration in the case of the Railways of the country. The Inter-State Commerce Commission, in response to a universal prejudice against railways and public service corporations generally,

systematically refused to give to them permission to raise freight or passenger rates to a point where they could earn a fair return on the capital invested, and also a sufficient surplus with which to maintain their properties in a state of efficiency, and provide new rolling stock, and new locomotives, new tracks, branch lines, etc., to meet the growing wants of increasing, and expanding business. This starving process had continued for years under the domination of political forces until the Inter-State Commerce Commission itself confessed that something must be done to save our great trunk lines of transportation, the vital arteries of the Nation's life, from universal bankruptcy. Just at this critical period in railway strangulation by the Nation's Public Service Commission (The Inter-State Commerce Commission), we became involved in the world war, and the Government took over the operation of the railways. The first thing it did was to raise passenger, freight, and all other rates 30 to 40 per cent, and even under these advances, has been losing over a half-billion dollars a year on their operation, so that the latest word from Director General Hines is that another large increase in freight rates is absolutely necessary before these properties are returned to their owners in order to keep them from disorganization and insolvency, and permit them to serve the transportation interests of the country satisfactorily and efficiently. Hence the "dear people" will now pay and pay in handsome figures for the folly of the Inter-State Commerce Commission, in denying so long to the railways adequate rates, in response to an uninformed and populistic demand from political forces which this weak Commission permitted to influence their action even against their better judgment. The same is true of the Street Railways of the country. Municipal bodies ,and Public Service Commissions have so long prevented in response to an unreasoning popular pressure, an adequate increase in fares to correspond with increased

expenses, that now in many cases, the fares are being doubled in order to keep these public necessities from going out of operation entirely. No business can exist for long if it is constantly losing money, and hence the people must eventually make up in a short time and often at great hardship what has been unwisely and unjustly withheld at the behest of an uninformed and unreasoning public outcry.

Why this great economic waste of abandoned gas works in the City of Wheeling upon which many hundreds of thousands of dollars of public funds have been expended? The main reason appears to be that two or three natural gas companies very foolishly and without any real knowledge of the ultimate cost of delivered natural gas vied with each other in offering to furnish her citizens a doubly superior gas at only about one-sixth the price at which the city was selling manufactured gas, and in addition to donate to the city several million cubic feet of free gas annually for her public buildings as a bonus in order to secure the coveted francise to sell natural gas within the municipality at figures which later proved to be less than cost, and which these same gas companies have ever since been struggling to have raised to a living profit. The mistake of the early producers of natural gas in affixing prices too low for profitable operation was a natural one. The average business man assumed that a the supply of natural gas was unlimited, and while turning deaf ear to the geologists who always warned him the supply would eventually fail through use and waste, he listened willingly and apparently approvingly to the fakers in science who assured him the supply of natural gas would never fail, that it was being manufactured at a rapid rate deep down in Nature's vast laboratory. This false doctrine of unfailing supply both aided in establishing prices too low, and discouraged the prevention of waste. The history of every gas field in the country like the nearly exhausted fields of Indiana and the Findlay region of northern Ohio proclaims the falsity

of the doctrine that natural gas is still being produced, and confirms the conclusion always advocated by the reputable geologists that like coal, or iron ore, there existed a definite quantity of it compressed in the earth's reservoirs and except for the small quantity held in solution in petroleum under great pressure, little or no additional to the original supply is possible so far as economic use is concerned. The declining rock pressures in every Appalachian gas field, a sure sign and measure of gas exhaustion, tell the consumer of natural gas in no uncertain tones that the day of abundant supply for him is rapidly passing unless the use of natural gas for manufacturing purposes is greatly restricted, and the vast wastes hitherto permitted are prevented. This gives rise to the question: **How can our natural gas supply be conserved for domestic purposes?** The enormous waste of natural gas that has taken place in every State of the Union would not have occurred, and would not still be permitted to go on, could the masses of the people have realized the great inherent value of this gas. When you tell them that its actual value for light (Welsbach), heat and power is practically double that of the richest gas manufactured in the retort oven, and five to seven times the value of producer gas, it does not seem to occur to the consumer that this inherent superiority should be reflected at all in the **price** of natural gas. The producer of natural gas has probably himself mostly to blame for this present frame of mind of the consumer. The producer and marketer of natural gas has never until quite recently had any proper accounting system whereby he could know what his gas was really costing. The words depletion, depreciation, loss from leakage, electrolysis, amortization of capital, etc., etc., the accumulation of surplus with which to extend his lines to distant gas fields, or with which to construct manufactured gas plants after the natural gas has failed to yield a supply sufficient for his consumers, were words and ideas practically unknown in his vocabulary.

One of the splendid by-products of the Federal Income Tax, is that it has taught the careless business men, as well as careless corporations, that they cannot continue in business in the old happy-go-lucky manner of a decade ago, when very few business men or organizations possessed any really adequate accounting systems, and hence were often like practically all coal and gas producing agencies at that time, actually losing money every month of the year and did not know it. This stage in the evolution of industry has happily passed, we hope never to return, so that under the spur of necessity even the coal and natural gas companies which prior to the world war had nearly all been selling their products below actual cost based upon any proper accounting system, are now beginning to realize that they must secure more adequate prices from the consuming public, or they cannot command the funds necessary to continue efficient service, or finally any service at all.

A city situated like Wheeling near a great gas coal deposit, a long time ago when labor received a reward of $1.00 to $1.25 for a day of 10 to 12 hours and the coal baron of that ancient period received 60 to 75 cents per ton for the best grade of gas coal, could manufacture and deliver gas to her citizens at 75 cents per 1000 cubic feet and not go immediately "broke". That she could not do so now with a $4.00 wage of 6 to 8 hours, and $2.75 to $3.00 per ton for coal at the mines admits of no discussion. In fact the average price of manufactured gas throughout the country would probably exceed $1.00 to $1.25 per 1000 cubic feet at the present date, and most of these gas companies are asking Public Service Commissions for permission to raise the price to the consuming public in order to enable them to continue efficient service.

As showing the tendency to advance the price at which manufactured gas used for household purposes was sold in the representative cities of the country during the year 1918,

and the increases that had been granted by Public Service Commissions up to April 15th, 1919, the following statement and compilation made by the United States Department of Labor should prove of special interest:

"Figures compiled by the Bureau of Labor Statistics of the United States Department of Labor show that advances in the price of gas for household purposes were general among American cities during the year ended April 15th, 1919. The increases varied from 5 per cent to 45 per cent, the latter being the advance in Buffalo, which went from $1 gas to $1.45."

"A general increase also was registered in the cost of natural gas and in manufactured and natural gas mixed. In Kansas City the price of natural gas went from 60 cents to 80 cents per 1,000 cubic feet. The advance to consumers of the District of Columbia was from 90 to 95 cents." Following is the report prepared by the Bureau of Labor Statistics on the prices of 1,000 cubic feet of gas used for household purposes:

MANUFACTURED GAS

	1918	1919
Atlanta	$1.00	$1.00
Baltimore	.75	.75
Birmingham	.95	.95
Boston Co.—A	.90	1.00
Boston Co.—B	.85	1.10
Boston Co.—C	.80	.95
Bridgeport	1.00	1.10
Buffalo	1.00	1.45
Butte	1.485	1.485
Charleston (S. C.)	1.10	1.10
Chicago	.755	.88
Cleveland	.80	.80
Denver	.85	.95
Detroit	.75	.79
Fall River	$ .95	$ .95
Houston	1.00	1.00
Indianapolis	.55	.60
Jacksonville	1.25	1.25
Manchester	1.00	1.10
Memphis	1.00	1.00
Milwaukee	.75	.75
Minneapolis	.77	.95
Mobile	1.10	1.35

	1918	1919
New Haven	1.00	1.10
New Orleans	1.00	1.30
Newark	.97	.97
New York	.80	.80
Norfolk	1.20	1.20
Omaha	1.15	1.15
Peoria	.85	.85
Philadelphia	1.00	1.00
Pittsburgh	1.00	1.00
Portland, Me.	1.00	1.40
Portland, Ore.	.85	.779
Providence	1.00	1.30
Richmond	.80	1.00
Rochester	.95	.95
San Francisco	.85	.90
Scranton	1.15	1.30
Seattle	1.25	1.25
St. Louis	.75	.75
St. Paul	.85	.85
Washington	.90	.95
Natural Gas		
Buffalo	.30	.35
Cincinnati	.35	.35
Cleveland	.30	.35
Columbus	.30	.30
Dallas—A	.45	.45
Dallas—B	.30	.30
Kansas City	.60	.80
Little Rock	.40	.45
Louisville	.648	.648
Pittsburgh Co.—A	.30	.35
Pittsburgh Co.—B	.275	.35
Manufactured and Natural Mixed		
Los Angeles	.68	.75

The large difference in price of manufactured gas as shown by the foregoing list, varying as it does from a minimum, 60 cents per 1000 cubic feet at Indianapolis to $1.485 at Butte, is doubtless in part due to the character of the gas furnished, since it varies in heating value from 120 B. T. U. to 600 B. T. U. while natural gas contains an average of 1100 B. T. U. per cubic foot and is therefore practically double the value of any other fuel gas. The prices in this

list will also show the domestic consumer of natural gas the approximate prices he will soon have to pay or else give up the use of gaseous fuel. This table should also convince the domestic consumer that it is to his very great interest to have the general use of natural gas for industrial purposes abandoned at the earliest possible date if he expects to escape for even a very few years from paying a high price for a fuel gas much inferior to that he is now using.

The domestic consumer should also remember that the rates given above for manufactured gas are based upon the cost of plants constructed before the late war, and that any new structures of any description will now involve a cost at least double that of pre-war prices so that there cannot be any hope of securing manufactured gas for domestic heat at anything less than the above figures, but the probabilities are that they will be considerably greater, since no capital can ever be induced to invest, in what seems on its face, to be plainly a losing venture. Then, too, in many of the cities listed above the companies supplying the same, have been asking Public Service Commissions and supervising authorities for a material advance in rates in order to enable them to continue in business without utter bankruptcy. For instance, in New York City where a rate of 80 cents per 1000 cubic feet is named, the Consolidated Gas Company supplying this manufactured gas has clearly demonstrated that it is losing money on every foot of gas sold at the rate in question, and has for two years or more been asking for a rate of $1.00 per 1000 cubic feet, and yet because this same great corporation owns some other public utilities upon which it has earned a profit, the New York political authorites in obedience to an unreasoning and populistic spirit have not yet granted any advance, although ultimately, the Courts will doubtless grant the necessary relief as they did in the case of the Arkansas Natural Gas Company in Kansas City, raising the price of natural gas 20 cents per 1000 cubic feet

after the local authorities had refused to permit any advance whatever.

In Part Number Fourteen will be found rates for gas sold in many Ohio and Indiana cities and towns.

The new rates for natural gas recently granted by Public Service Commissions in Ohio and Indiana would lead to the conclusion that even these over-conservative and slow-to-act bodies are beginning to realize that the producer and supplier of this matchless fuel must receive more adequate compensation or service can not be continued.

The reasonableness and the necessity of granting large advances over the old prices of natural gas are also clearly shown by the great increase in the cost of drilling either oil or gas wells since 1913. Drilling costs for oil and gas wells in West Virginia and Oklahoma fields will be found on pages 202 and 203.

With the known cost of manufactured gas, and the failing supply of natural gas what should the domestic consumer do who does not desire to return to the use of coal or wood in his house-hold? That the natural gas companies cannot much longer furnish an adequate supply for domestic consumption without greatly curtailing the industrial use of natural gas is evident to all who have exact knowledge on the subject. The main problem appears to be how best to bring about the readjustment which will conserve an adequate supply of natural gas principally to the domestic consumers for many years to come. To those who have studied the question most profoundly there would appear to be but one answer, viz: a large and gradual increase in the price at which natural gas is now sold. It has never secured an adequate price. Double the heating value of the best manufactured gas, cleaner and freer from impurities, it has always been sold at only a fraction of the actual cost of the manufactured article. This cheapness has led to waste at every step of its

production, marketing and burning; waste at the well mouth; waste along the pipe line; waste at the burner; waste in using a prescious, pure and refined fuel where coal would answer every demand for power. Let us suppose that the Public Service Commissions of Ohio, West Virginia, Pennsylvania and Kentucky would in the near future authorize the companies supplying natural gas gradually to raise the price of this commodity to say 50 cents and finally $1.00 per 1000 cubic feet for this priceless fuel, and see what would almost certainly happen. The first result would be a gradual return to coal for most industrial purposes. The second would be the installation of more efficient burners and more intelligent use of the same thereby securing all necessary heat for domestic purposes with less than one-fourth of the quantity now burned in which 80 per cent is pure waste. This greater utilization would **decrease** instead of **increase** the consumers present monthly gas bills.

What would happen in the producing fields? All avoidable waste would be prevented by the self-interest of the owners. No oil wells would be permitted to vomit into the air thousands of dollars worth of gas daily since their owners would be losing too much money and the strongest of all laws, that of self-interest would lead to the separation of the oil from the gas, and the marketing of the latter instead of permitting it to waste into the air as at present. The producer could afford to pay the farmer an adequate price, 10 to 15 cents per thousand cubic feet for his gas in the ground; the conservation of gas would take care of itself; everyone would have plenty even on the coldest days of winter, and the field supply might last for 30 or even 50 years, especially if the plan pursued in some regions of Ohio and Indiana during the past year were adopted; viz., that of alloting to each household the quantity fo gas which would be amply sufficient to do the heating and cooking required for the house in question when proper burners were used in

a proper manner, any excess over these standard amounts (which of course would represent so much waste and unnecessary depletion of the general supply) to be charged for on a **rising** scale of rates per 1000 cubic feet instead of a **decreasing** scale, as is now the general custom to large consumers. Where ever this policy has been adopted, even in the nearly exhausted gas fields of Indiana, complaints of gas shortage have ceased, and all consumers have been satisfied even during the coldest weather. This policy puts the burden where it belongs, viz., upon the wasteful and careless, and effectually reaches them by the most convincing af all arguments, the appeal to their pocket-books.

But how, you may well ask, would a large increase in the price of natural gas affect the incomes of the producing and marketing companies? Undoubtedly the first effect would be greatly to reduce their present incomes from the sales of gas. Mt. Harry J. Hoover of the Columbia Gas and Electric Company, Cincinnati, Ohio, in a splendid paper read before the recent meeting of the Natural Gas Association of America at Cleveland, Ohio, has clearly shown that of 477,041 consumers in the region of Ohio served by several corporations, and paying an average of 35 cents per 1000 cubic feet, 62 per cent or 277,262 of these consumers were served with gas at an actual loss, while the 38 per cent or only 199,779 of the remaining consumers (and these are the larger ones) are compelled to carry this expense of the other two-thirds over and above the actual cost of service. These illuminating figures of Mr. Hoover demonstrate that with the present low prices of natural gas, it is only from the large and wasteful consumers that the natural gas companies are now able to live, and pay a small dividend to their stockholders, and hence, the continuation of such economic conditions beyond a very short period is unthinkable. It also illustrates the folly of selling a gas worth at least $1.00 per 1000 cubic feet at the consuming point for 20 to 35 cents. That doubling or

trebling the present prices of natural gas to consumers would greatly decrease the income to the marketing corporations from the sales of gas admits of no doubt, but on the other hand their expenses would at the same time be greatly curtailed. At least 50 per cent of present drilling and field expenses could be immediately eliminated, while the increased income from the many households that will always remain wasteful would in large measure reimburse the loss of industrial consumers, so that the net results in the prolongation of the life of our gas fields, would in the end fully recompense the natural gas producing and marketing companies for the immediate loss of revenue which all are sure to sustain by any radical increase in rates.

But suppose our Public Service Commissions refuse to permit this suggested raise in price of natural gas, what is going to happen? With the failing supply, it requires no prophet to foretell that the waste of this precious gas will continue; small wells instead of being utilized will be abandoned; service will become more and more unsatisfactory both to domestic and industrial consumers and with the doubled cost of drilling many of the companies will be compelled to go out of business entirely, since, no one can manufacture gaseous fuel to add to and help to supplement the waning supply of natural gas at less than $1.00 per 1000 cubic feet, and then it would have only half the heating value of the natural product, and yet without this supplementary gas, the business of marketing gaseous fuel must inevitably soon be much restricted, thousands of customers cut off every year for want of gas, and finally the entire business come to an end disastrous alike both to consumer, because it will deprive him of the great convenience of gaseous fuel, and to the producer, because he will have suffered large financial loss.

That this discontinuance of service to whole cities and communities is not a hypothetical condition but an actual

reality is attested by the recent withdrawal of the Pennsylvania Gas Company from Jamestown and other communities in southwestern New York, because municipal authorities refused to grant remunerative rates. It has also been published that the East Ohio Gas Company will soon withdraw service from one of your own cities in Ohio, viz., Alliance where the city authorities are unwilling to grant a living rate. These instances should be warning to other communities as to what is in store for them if they permit their public authorities to attempt to secure the most valuable fuel in the world at less than cost when other communities are not only willing but anxious to pay a remunerative price for this matchless fuel in harmony with the greatly advanced cost of securing and delivering natural gas to the consuming public.

Summary of Conclusions.

Looking back across a span of years which has seen the rise of both the oil and gas industry, and speaking as a business man and also as a State Geologist and in that sense a kind of guardian of mineral resources, my studies have led me to the following conclusions concerning the natural gas situation in the Appalachian fields:

(1) Approximately three-fourths of the original supply of natural gas in the Appalachian fields is already exhausted, much more than half of which has been wasted without any attempt at utilization.

(2) Of the portion used for domestic purposes at least 70 to 80 per cent is now wasted through the use of crude burners resulting in bright flames instead of blue, and also through lack of intelligent methods of applying the flame to the object to be heated.

(3) Natural gas practically double in heating value the best grade of manufactured gas has always been sold too cheap, and this more than any other cause has led to its universal waste and wasteful use.

(4) It is such a pure and cleanly fuel and so limited in supply that it should have been preserved entirely for domestic use, and its introduction into general industrial purposes was an economic mistake which should speedily be remedied.

(5) The only effective means of conserving the waning supply of natural gas, and prolonging its life to a distant future for domestic purposes is to raise the price of the same gradually until it approaches the cost at which manufactured gas can be furnished for fuel purposes, since otherwise it will be impossible for the producing and marketing companies to maintain a satisfactory supply to those who prefer to use gaseous fuel.

(6) This increased price (even two or three times) over that now charged the domestic consumer would not necessarily increase the cost of his fuel bills over that which he now pays, in fact in most cases it would lead to a reduction of the same through the intervention of more efficient burners and more intelligent use of the same whereby the 80 per cent of the available heat in natural gas now ordinariily wasted by the consumer, would be conserved and utilized. During the colder months of the year, at least, an advancing rate should be charged those who consume large quantities of gas in a wasteful manner, and the industrial use of natural gas should be restricted to those manufacturing concerns that can from the nature of their product afford to pay the domestic rate, since the gradual rise suggested in natural gas rates would enable manufacturing enterprises to change without hardship to other forms of fuel, or if they desire, install their own fuel gas plants, thus availing themselves of gaseous fuel at first cost.

(7) Should our Public Service Commissions adopt the policies herein suggested, the following benefits would come to all:

(a) Waste of gas would soon be effectually checked not only in the field, but along the great pipe lines as well as at the points of consumption.

(b) The farmer or original owner of the gas could be paid a much larger sum for the right to secure, and transport this product to market.

(c) The life of the Appalachian gas fields could be so greatly prolonged, just how many decades no one can accurately forecast, that manufactured gas could gradually and insensibly replace the vanishing natural product without any interruption in the supply of gaseous fuel so greatly prized by those who have enjoyed the wonderful convenience of its use.

(d) Gas shortage and inefficient service would be things of the past, and while the income of the gas companies would certainly be greatly decreased at first with the decreased consumption which higher rates are sure to cause, especially in manufacturing enterprises, yet the decreased expense incident to drilling so many new wells in a vain effort to keep up the failing supply, would tend to offset the smaller receipts to a considerable extent, and finally with increasing prices enable them to earn a reasonable profit, as also gradually to supplement the deficiency of natural gas with the manufactured product, and thus continue indefinitely in the business of supplying fuel gas to their patrons instead of gradually cutting off one consuming center after another with the failing natural gas supply, and finally junking the entire outfit.

(8) In view of these conclusions which are as surely true, as that two and two make four, why should not the domestic consumer of natural gas in his own interest join the producer in beseeching our Public Service Commissions to increase the present ruinously low rates for this product, not a few cents per thousand cubic feet each **year,** but a few cents every **month,** until the price of the same approaches $1.00 per 1000 cubic feet, the basic cost at

which a good grade of manufactured gas can be supplied with which to augment the declining supply of this natural article, instead of opposing every effort at price readjustment upward which immutable economic law must eventually compel with all the evils attendant upon the disorganization and failure of a great industry?

Gas Bearing Strata—The gas bearing stratum which when pierced by the drill produces natural gas is sometimes called a "gas vein," a "gas pool," a "gas reservoir," a "gas sand," etc. Practical geologists quite often can locate an anticline or a syncline or other formation where gas or oil is likely to be found but the drill is the only positive way of telling where there is an underlying gas filled strata.

The sand itself must be porous in order to contain gas or oil, and most important of all, the gas bearing strata must be covered by an upper stratum of hard non-porous rock, commonly called the "shell" which prevents the gas from gaining an outlet to some upper strata. The tendency of gas is to move upward or parallel to its source until its movement is checked by a non-porous rock or the gas escapes into the atmosphere, as is commonly found at outcroppings. Generally the larger the pores or the coarser the sand in a gas bearing stratum the shorter the life of the gas from that particular sand.

The area and thickness of a gas bearing stratum of sand varies greatly. It may be 40 feet thick in one spot and only 100 feet distant but 2 feet thick or even void of any pores in which the gas is confined. It may be miles in length in one direction while it but a few hundred feet wide. Its edges may be round in outline or it may be oval. There is absolutely no rule or theory to go by in determining the area or shape of a known gas bearing stratum. It can only be determined by the drill.

There may be two gas wells a hundred feet apart with no connection between the gas bearing strata.

Remarkable Natural Gas Reservoirs in North America—No other country has produced more than a small fraction of the natural gas produced by the United States and Canada.

While mainly confined to the valley of the Mississippi, the gas areas have greatly increased and are now to be found in Ontario, Alberta, New York and California. The main areas of Pennsylvania, West Virginia and Ohio have developed remarkable staying qualities, and considerable new production. These three States produce two-thirds of the total production of this continent. Indiana is the only State that has shown any appreciable falling off in the production of gas. In this State gas was found principally in the Trenton limestone, here, as in the Trenton limestone of Central New York, the supply is soon exhausted. It has been generally considered by geologists that the origin of natural gas is below the Trenton limestone, as this limestone has never shown the proper formation to produce natural gas in paying quantities, probably due to the amount of cement which it carries, which has a great tendency to form pockets.

The mid-continental field has shown a greater increase in production, than any other natural gas area. The Kansas production has dropped off considerably, but it has been offset by the development of new areas, such as Tulsa, Ponca City, Ossage Nation, Choteau, Collinsville, Ada, Duncan and many smaller fields in Oklahoma; Ranger, Petrolia, Mexia, Laredo, Thurber, Albany and Trickham, Texas; Monroe, Houma, Caddo and DeSotto Parish in Louisiana.

The New York and Ontario fields where gas is found in the Medina sandstone have never developed any large wells, but have gradually spread out over an extensive area, and have shown wonderful staying power. Instances are known to the writer where wells in New York state have produced gas in paying quantities from twenty to twenty-five years, and are still good producers.

The Alberta field has developed many exceptionally large wells. The great volume already produced can be taken as a

very good indication of the Alberta field as a gas-producing province.

The Wyoming field has proven to be very productive of gas and oil in many different counties.

Small gas areas are to be found in Illinois, Kentucky, California, Alabama, Colorado, New Mexico, Oregon and South Dakota. None of these fields are fully developed, consequently it is impossible to predict what the future will produce.

In foreign countries there is some gas produced in Russia, Persia, Roumania, Galicia, India, Japan and Mexico. England produces a limited amount.

In the year 1917 the total production of natural gas in the United States and Canada was nearly eight hundred billion cubic feet.

It is estimated that not less than fourteen million of our inhabitants are enjoying the benifits of this ideal fuel, as a source of heat, light and power.

Many of the natural gas pools in the United States are associated with petroleum producing areas, to which they often form a fringe or border near by, the gas occupying the higher portions of the same strata that contain the petroleum. There are, however, numerous areas that produce large quantities of natural gas that are completely isolated from any petroleum production.

Productive Natural Gas Horizons—The chart of productive natural gas horizons shown on the following page was prepared with a view of showing the various oil and gas sands with reference to their age and position in the stratified rocks forming the earth's crust. Owing to the fact that some of the oil fields have not been given thorough geological study and also that geologists are not yet certain regarding the age of several of the formations, this chart is of course approximated. Asterisks (*) indicate uncertainty.

TABLE No. 1—SHOWING PRODUCTIVE NATURAL GAS HORIZONS

Era	Geological System	Geological Series of Group		Producing Formation or Sand	Locality Where Productive
CENOZOIC	Quaternary	Recent Series		Alluvial Deposits	Beaumont, Tex. Jennings, La.
	Tertiary	Pliocene *			
		Miocene Series	Upper Miocene	Jacalitos Formation	Coalinga, Cal. McKittrick-Sunset, Cal.
				Fernando Formation	Santa Clara River, Cal. Los Angeles, Cal.
			Middle Miocene	Monterey Shale	Santa Maria, Cal. Summerland, Cal.
				Puente Formation	Los Angeles, Cal. Salt Lake District, Cal.
			Lower Miocene	Vaqueros Sandstone	Coalinga, Cal. McKittrick-Sunset, Cal. Santa Clara River, Cal.
		Eocene Series		Tejon Formation	Coalinga, Cal.
				Sespe Formation	Santa Clara River, Cal.
MESOZOIC	Cretaceous	Upper Cretaceous		Chico Formation	Coalinga, Cal.
				Mancos Shale	Colorado Lander, Wyo. Wind River, Wyo.
				Dakota Sandstone	North Dakota Alberta, Canada (Gas)
				Webberville Formation	Corsicana, Tex.
				Aspen Formation	Spring Valley, Wyo.
				Colorado Formation	Big Horn Basin, Wyo.
				Wall Creek Sandstone (Lentil of Benton Shale)	Salt Creek, Wyo.
				Nacatoch Sand	Caddo, La. (Gas)
				Woodbine Sand	Caddo, La. (Oil)
		Lower Cretaceous		Trinity Sand	Medill, Okla.
	Jurassic			Sundance Formation	N. E. Wyoming
	Triassic	*		Chugwater Formation	Wyoming

TABLE No. 2—THE LOWER GEOLOGICAL SERIES IN KENTUCKY AND THE CORRESPONDING OIL AND GAS SANDS*

System	Series	Producing "Sands"	Notes
Pennsylvanian	**CONEMAUGH** Coals, shales, sands.	Exposed and ridge sands.	All above drainage.
	ALLEGHENY Coals, shales, sandstones.	Exposed sands.	Mostly above drainage.
	POTTSVILLE Conglomerate shales, coals and massive sandstones.	"Beaver" "Horton" "Pike" "Salt" — Sands of Floyd, Knott and Pike Cos. "Wages" "Jones" "Epperson" — Sands of Knox Co.	Corresponds in part to Pottsville Conglomerate of Ohio, West Virginia and Pennsylvania.
Mississippian	**CHESTER** Shales, limestones and sandstones. Mostly limestones. Some shale and sand.	"Maxon" of Floyd and Knott.	Corresponds to "Mauch Chunk" of West Virginia and Pennsylvania.
		"Big Lime" gas sand inclusion in Pike, Martin, Floyd and Knott Counties.	St. Louis limestone. Corresponds to "Mountain Lime," and "Greenbriar Lime."
	WAVERLY Sandstones and shales in Eastern Kentucky; limestones in Western Kentucky.	"Big Injun," "Squaw Sand," "Keener," "Cloverport Gas Sand" "Wier Sand," "Berea Grit." "Stray" "Mt. Pisgah" "Beaver" "Otter" "Cooper" "Slickford" — Sands of Wayne County Barren County amber oil sand.	Corresponds to "Pocono" slates of West Virginia.

* From "Resources of Kentucky" No. 1, Vol. 1, Series 2. By W. R. Jillson, State Geologist.

THE LOWER GEOLOGICAL SERIES IN KENTUCKY AND THE CORRESPONDING OIL AND GAS SANDS*—Continued

System	Series	Producing "Sands"	Notes
Devonian	**GENESEE** Black shale.	Meade County gas sand, "Oil shale"	Corresponds to the "Chattanooga" shale.
	ONONDAGA Limestone.	Ragland, Irvine, Menifee, Big Sinking, Campton, Gainesville "sands"	Porous in places. "Corniferous" limestone.
Silurian	**NIAGARA** Limestones and shales.	Boyd's Creek "sand" of Barren County, and possibly an Allen County "sand."	A localized producer only.
	CLINTON Limestones and shales.	Clinton of Morgan County.	Top of Great Limestone Series.
Ordovician	**CINCINNATIAN** Limestones, blue shales, some sandstone.	"Caney Sand." "Upper Sunnybrook." Barren County "Deep Sand." Cumberland County "Shallow Sand."	Richmond, Maysville, Eden and Cynthiana.
	MOHAWKIAN Mostly limestones, some shales.	"Lower Sunnybrook." "Trenton Sands"	Lexington or Blue Grass limestone.
		Barren, Wayne, Clinton and Cumberland Counties. Lower "Sands"	Stones River, Kentucky River, Birds-eye, Magnesian, Black River, and Chazy. (Above and below drainage.)
	Dolomitic limestone.	"Deep Sand" Wayne County.	"Knox Dolomite" in Southern Kentucky. (All below drainage.)
	White sandy limestone.	Salt water sand at top. "Deep Gas Sand," Estill County.	"Calciferous." (All below drainage.

NOTE—Black horizontal lines indicate unconformable or disconformable strata.

* From "Resources of Kentucky," No. 1, Vol. 1, Series 2. By W. R. Jillson, State Geologist.

The following table by F. H. Oliphant shows the strata in descending order, that are known to contain natural gas in greater or less quantity in the localities named, beginning with Pittsburgh coal, which caps the upper barren measures of the Carboniferous, and extending to the Quebec group of the Cambrian. The distance from the Pittsburgh coal to the lower Trenton is given approximately, and the approximate intervals can be found by subtracting one from the other.

It must not be inferred that all of the strata named are universally productive, but that the horizons in the localities named are productive.

In the northeastern portion of the Mississippi Valley natural gas occurs principally in the strata beginning with the higher Carboniferous down to the bottom of the Trenton, a distance of over 9,000 feet. The rocky reservoirs, and strata associated with them, vary considerably in thickness and texture. This section is compiled from records of wells near McDonald, Allegheny County, Pennsylvania, and extends northeast to central New York, where the lower strata are productive.

The fact that the very lowest rocks of the Trenton limestone yield the greatest known gas pressure, amounting in New York to 1,500 pounds to the square inch, indicates that all of these different horizons are supplied from a common deep-seated source, and that the gas is not indigeneous to the strata in which it is found stored. This common source is probably deeply covered by Paleozoic rocks which have been more or less disturbed by folds that have produced slight fractures in the strata. These have served as vents for the passage of natural gas into the overlying porous strata, where it is found to-day. Many of these sands contain large quantities of petroleum, but pools of natural gas are much more generally distributed and occupy a much larger area than the pools of petroleum, both of which have a common origin.

TABLE No. 3—PRODUCTIVE NATURAL GAS HORIZONS (*By F. H. Oliphant*)

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Conemaugh or Barren Measures XIV	Pittsburgh sand, capping Pittsburgh Coal	West Virginia	0
	Connellsville sand	West Virginia	40
	Morgantown sand	West Virginia	80
	"Hurry up" sand	S. W. Pennsylvania and West Virginia	325
Allegheny or Lower Productive XIII	Mahoning or Dunkard sand	S. W. Pennsylvania and West Virginia	485
	Upper Freeport or second Cow Run sand	S. E. Ohio, S. W. Pennsylvania and W. Va.	630
	Ferriferous limestone	Not productive	850
Pottsville XII	Tionesta, Homewood or Johnson Run sand	S.E. Ohio, S.W. Pennsylvania and W. Va.	920
	Upper Conoquenessing or upper salt sand	S.E. Ohio, S.W. Pennsylvania and W. Va.	970
	Lower Conoquenessing or middle salt sand	S.E. Ohio, S.W. Pennsylvania and W. Va.	1,060
	Sharon Conglomerate, Orlean lower salt or Maxon sand	Kansas and Indian Territory, S. E. Ohio, S. W. Pennsylvania, West Virginia and E. Kentucky	1,140
Mauch Chunk XI	Mountain limestone	Not productive	1,225
	Keener sand, sandy limestone	S. E. Ohio and West Virginia	1,345
Pocono X	Big Injun or Sub Olean sand	West Virginia, S. W. Pennsylvania, S. E. Ohio and E. Kentucky	1,375
	Squaw sand	West Virginia, S. W. Pennsylvania, S. E. Ohio and E. Kentucky	1,465

PRODUCTIVE NATURAL GAS HORIZONS—*Continued*

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Catskill IX or Upper Devonian	Upper gas sand	S. W. Pennsylvania	1,535
	Berea or Butler County gas sand	S. W. Pennsylvania, West Virginia, Ohio and Kentucky	1,730
	Devonian or Ohio shales	W. New York, N. W. Pennsylvania, N. E. Ohio, W. Kentucky and S. Indiana	1,750
	First sand or Gantz (100-foot sand)	W. Pennsylvania, West Virginia and S. W. Ohio	1,855
	50-foot sand	W. Pennsylvania and West Virginia	1,910
	Second or 30-foot sand	W. Pennsylvania and West Virginia	2,010
	Gray, Stray or Boulder sand	W. Pennsylvania and West Virginia	2,070
	Third or Gordon sand	W. Pennsylvania, West Virginia and S.E. Ohio	2,130
	Stray third sand	W. Pennsylvania and West Virginia	2,145
	Fourth sand	S. W. Pennsylvania and West Virginia	2,200
	Fifth sand	S. W. Pennsylvania and West Virginia	2,260
	Bayard sand	S. W. Pennsylvania and N. West Virginia	2,420
Lower Devonian VIII	Elizabeth or sixth sand	S. W. Pennsylvania and N. West Virginia	2,590
	Warren first sand	N. W. Pennsylvania	2,685
	Warren second sand	N. W. Pennsylvania	2,800
	Clarendon or Tiona sand	N. W. Pennsylvania	2,885
	Speechley sand	N. W. Pennsylvania	3,000
	Balltown or Cherry Grove sand	N. W. Pennsylvania and W. New York	3,120

PRODUCTIVE NATURAL GAS HORIZONS—*Continued*

Geological Equivalent	Natural Gas Horizons	Locality Where Productive	Approx. Depth Below Pittsburgh Coal
			Feet
Lower Devonian VIII	Sheffield or Copper sand	N. W. Pennsylvania and W. New York	3,320
	Bradford or Deer Lick sand	N. W. Pennsylvania and W. New York	3,430
	Elk sand or Waugh and Porter sand	N. W. Pennsylvania and W. New York	3,645
	Kane sand	N. W. Pennsylvania and W. New York	3,775
	Black shales bottom of Devonian	N. W. Kentucky, S. Indiana	5,325
	Hamilton limestone	S. W. Ontario, Canada	5,330
	Corniferous	New York and S. W. Ontario, Canada	5,625
	Oriskany sand	S. Indiana, S. Ontario, central New York	5,660
Silurian	Guelph limestone	S. Ontario, W. New York	5,700
	Niagara limestone	S. Ontario, W. New York and Indiana	5,820
	Clinton limestone	S. E. and Central Ohio and S. E. Ontario	5,985
	Medina red sand	S. E. Ontario, W. New York and Ohio	6,085
	Medina upper white sand	S. E. Ontario and W. New York	6,185
	Medina white sand	Central New York	6,240
	Trenton limestone, upper portion	Ohio, Indiana and Kentucky	8,700
	Trenton limestone, lower portion	S. E. and Central Ontario and N. Central New York	9,225
Cambro-Silurian	Calciferous and Potsdam sand	S. E. Ontario and Central New York	.....
Cambrian	Quebec group, sands and shale	Alabama, Georgia and N. W. Newfoundland	.....

First Use of Artificial Gas—In the year 1812 the Gas Light and Coke Company of London obtained a charter to supply gas to that city. William Murdock was the inventor of coal gas and lighted his home with it in the year 1792. He was connected with the above mentioned company when they first applied for their charter, three years before it was finally granted.

At the time of the first application before the House of Parliament, a great deal of ridicule was directed toward Mr. Murdock and his company.

"Do you mean to tell us," asked one member, "that it will be possible to have a light without a wick?"

To which Murdock answered in the affirmative, for the best of all reasons—that he himself had produced a light with gas.

"Ah! my friend," said the representative of the people in the House, "you are trying to prove too much."

Men, talented and educated, heaped ridicule upon the work of the little band of heroes who forgathered at Soho, Birmingham. Sir Walter Scott, great as was his admiration for James Watt, made various smart jokes about the absurdity of lighting London with smoke. People implicitly believed that the gas was carried through the pipes on fire. and they foresaw awful results from red-hot metal.

To-day the Gas Light and Coke Company of London has a capital stock of $150,000,000 and in the year 1911 burned two million tons of coal and made about twenty-seven billion feet of gas.

History of Natural Gas—Natural gas was known to exist in China, Persia and British India for many centuries, although it was never put to commercial use. It appeared as leakage from gas-bearing strata through crevices in the ground, and when lighted by the natives, it was worshipped as a fire "god."

At a burning well near Baku, Russia, are the ruins of an old Parsee temple, dedicated to the God of Fire.

In this country, as early as 1775, George Washington dedicated to his country, as a national park, a tract of land which he had preempted, in West Virginia, containing a burning spring. This, too, was leakage from a crevice in the ground.

The first discovery of natural gas by drilling in the United States occurred through the drilling of shallow wells for salt in Ohio and West Virginia, and probably dates back to early in the nineteenth century.

Along the Muskingum River in Ohio in the early thirties many salt wells were drilled to a shallow depth of from three hundred to four hundred feet. These wells were located along the river from Stockport to Duncan and the making of salt became an industry of importance.

Rufus Stone, one of the first operators in the salt making business at McConnelsville, in the Morgan field, in drilling for salt struck a vein of natural gas strongly impregnated with sulphur, which caused the drillers to exclaim "we have drilled through into hell."

At first Mr. Stone considered the well a failure but later Captain Harry Stull solved the problem for him, making the gas boil the water in making the salt. This was continued for forty years.

The first actual use of natural gas for light occurred in Fredonia, New York, in 1826, but it was not until 1872 that Titusville, Pennsylvania, was piped for natural gas for domestic purposes, the gas being delivered through a two-inch line from the Newton well about five miles north of Titusville.

From that time the natural gas industry has had a phenomenal growth, increasing from a domestic service to perhaps a hundred people to the present total of about two and a half million consumers, serving approximately fourteen million people.

Natural Gas in Fredonia, N. Y.—The "*Penny Magazine*," a London weekly, on August 26, 1837, published an article taken from "*Brewster's Journal*," under the date of 1830 and which is reprinted herewith as a matter of general interest:

VILLAGE LIGHTED BY NATURAL GAS

The Village of Fredonia, in the Western part of the State of New York, presents this singular phenomenon. I was detained there a day in October of last year, and had an opportunity of examining it at leisure. The village is forty miles from Buffalo, and about two miles from Lake Erie; a small but rapid stream, called the Canadoway, passes through it, and after turning several mills, discharges itself into Lake Erie below; near the mouth is a small harbour with a lighthouse.

While removing an old mill which stood partly over the stream in Fredonia, three years since, some bubbles were observed to break frequently from the water, and on trial were found to be inflammable. A company was formed, and a hole an inch and a half in diameter being bored through the rock, a soft, fetid limestone, the gas left its natural channel and ascended through this. A gasometer was then constructed, with a small house for its protection, and pipes being laid, the gas is conveyed through the whole village. One hundred lights or less are fed from it, at an expense of one dollar and a half yearly for each. The flame is large, but not so strong or brilliant as that from gas in our cities; it is, however, in high favour with the inhabitants. The gasometer, I found on measurement, collected eighty-eight feet in twelve hours during the day, but the man who has charge of it told me that more might be procured with a larger apparatus. About one mile from the village, and in the same stream, it comes up in quantities four or five times as great. The contractor for the lighthouse purchased the right to it, and laid pipes to the lake; but found it impossible to make it descend, the difference in elevation being very great. It preferred its own natural channels, and bubbled up beyond the reach of its gasometer. The gas is carburetted hydrogen, and is supposed to come from beds of bituminous coal; the only rock visible, however, here, and to great extent on both sides along the Southern shore of Lake Erie, is fetid limestone.

THE FIRST OIL WELL IN AMERICA AT TITUSVILLE, PA., AUGUST 27, 1859

Fig. 21—THE DRAKE WELL

This well was 69½ feet deep and produced 20 barrels of oil per day for one year. The man with the silk hat is Col. E. L. Drake, and the man on his left is Peter Wilson, his friend. The boys on the right, are the sons of Wm. Smith, the driller, who assisted their father. They commenced drilling on May 20, 1859, and completed the well on Saturday, August 27, 1859. This photograph was taken on August 17, 1861.

THE BLOOMFIELD & ROCHESTER NATURAL GAS LIGHT CO.

Historical Sketch of the Well and Wooden Pipe Line 1863-1872.

By F. L. Kellogg

"When the great oil excitement in Pennsylvania was at its height and had extended into New York State, several companies were formed to put down test wells in places

Fig. 22—SECTION OF BLOOMFIELD-ROCHESTER WOODEN PIPE LINE, SHOWING JOINT

where gas came to the surface. Several gentlemen in West Bloomfield, N. Y. having discovered surface gas contracted for a 500 foot test well at a cost of $2,500. The Contractor had had little experience in well-drilling and the work progressed very slowly. His equipment consisted of a 2-inch

soft laid cable, a string of tools which weighed complete only 700 lb. and consisted of a sinker and chisel edged bit. A reamer was used in turn to keep the hole round. About 30 feet of 8-inch cast iron soil pipe was used for conductor, there being no other pipe used in the well. They had considerable water to contend with, which slowed up the work and several fishing jobs, one of which took 6 months to com-

Fig. 23—WOODEN PIPE SHOWING BELL JOINT

plete. But finally in the summer of 1865, after more than two years of effort, a large vein of gas was struck in the Lime at a depth of 480 feet. So much gas came that it was several weeks before they were able to continue drilling to the contract depth of 500 feet.

The Rock pressure was never known as there were no pressure gauges at that time available. An effort was made

to measure the open flow by filling a large balloon. The figures are not available to the writer but estimates made by those who worked on the well and have since had experience in estimating such matters, place the rock pressure at not less than 200 lb. and the open flow at least 200 M. cubic ft. daily, some claiming as high as 500 M. cubic feet.

Fig. 24—CROSS SECTION OF WOODEN PIPE

The stockholders were overjoyed at this evidence of success and expected every day that the flow of gas would diminish and the oil would come. After many weeks of waiting and no oil came, they gave up hope and the project was abandoned. Later in the year the gas was lighted and the flames shot over the top of the 40 ft. derrick and destroyed all the equipment. The light could be seen for many miles,

a dancing pavilion and dining hall were erected and many a gay party was held there. To this day the older inhabitants speak of it as "The Old Burning Well."

During the year 1870 some parties from Elmira, N. Y., came and examined the well, became interested and purchased the well together with 10 acres of land surrounding it. The Bloomfield and Rochester Natural Gas Light Company was formed, and in the Fall work was started laying a pipe line to Rochester, a distance of about 25 miles. Twenty acres of the finest of Canadian White Pine were cut to furnish the material for the pipe. The logs were cut into lengths of from two to eight feet according to soundness of the timber, and sorted to insure perfect wood. They were then turned to a diameter of 12½ inches and bored to 8 inches. Each pipe was bored on the bell end to a diameter of 10 inches and about 4 inches in and a band of iron shrunk around it. The other end was turned to fit the bell. They were then tarred inside and out.

The joints were made by dipping the end in hot tar and driving it into the bell. A stick of hard wood about 12 inches diameter by 3 feet in length was hung by a rope from a horse above the ditch. This served as a battering ram and two men could drive a joint home with an average of 9 blows. As experience was gained, as high as 240 joints were made in one day.

The ditch varied from 3 to 10 feet in depth. There was no give to the pipe and very little flexibility to the joints so that the line could not conform to the uneven ground surface and the ditch had to be dug nearly to grade. There were no elbows or similar fittings so that the turns had to be very gradual. Iron gate valves, similar to those in use today, were inserted in the line at frequent points. The gas was carried along with the work and as each gate was placed it was closed so as to hold back perhaps 8-lb. pressure and tests for leaks were made. These gates were not closed tight for

fear that the well pressure would blow up the line. Very few leaks were found in the joints, but such were repaired by wrapping the joint with burlap soaked in tar and secured in place by two half rings of band iron bolted together. Leaks due to defective pipe were repaired by wrapping the pipe with many thicknesses of burlap soaked in tar and the ditch filled in to secure it in place. When the supply of burlap gave out and no more could be obtained, the finest of woolen blankets were torn into strips and used. Nothing was allowed to delay the progress of the work, even though difficult engineering problems were met, no expense was spared.

A tight line and a good flow of gas at a good pressure was carried up to a point about five miles from Rochester when trouble came. Labor trouble necessitated the removal of the Superintendent in charge of the work and his successor, being overzealous, shut one of the gate valves tight in an effort to see just how good a job was being done. The result was disastrous for the line was damaged so that leaks everywhere occured and scarcely a pound pressure could be secured. After some delay the line was continued and in the winter of 1872 the gas was turned into the mains of the Rochester Gas Company.

Just how much was delivered was never known. Immediately complaints began to come in of the poor quality of the gas and it was shut off never to be used again. The gas was the usual grade of dry natural gas with some hydrogen sulphide content, and had very little illuminating power in the open flame burners used at that time. Mantles and bunsen burners were unknown and so the gas was considered of no value.

The venture cost about one and one-half million dollars and was a total loss. Several years later, about eighty thousand dollars were spent in an effort to increase the illuminating value of the gas by passing it over heated lime

and charcoal, but although they succeeded to some extent, the idea was not practical and the entire project was abandoned. The well remained open for a number of years when the present Gas Company secured control and it was utilized for some time. Water gradually got the better of the gas and today there is only a trace of gas found. However, there are several shallow wells nearby, which furnish private families, but in quantities too small to be available commercially."

HISTORY OF PIPE*

In the early history of man's endeavor to solve the difficulties of mere existence, some sort of tube for the conveyance of fluids must have been employed.

Probably the "bamboo," which in tropical countries grows to five or six inches in diameter at the base, was used. It is today frequently used by "coolie" gardeners for conveying water along the surface of the ground for short distances.

The next step was a "pottery" tube, and these are found in Egyptian, Aztec and other prehistoric remains, which are brought to light by the excavations of archaeologists.

There is ample evidence that lead tubes were largely used in Grecian and Roman civilization. In many museums lead pipe and bronze water faucets (closely resembling the modern faucet) are shown which were recovered from the ruins of Pompeii and Herculaneum, and other buried cities.

Pliny, whose writings cover about the last three-quarters of the first century A. D., states that "in order to raise water up to an eminence leaden pipes must be employed."

First Iron Tubes—Probably the first imperative need for iron tubes was for the manufacture of gun barrels. After the invention of gunpowder, the first cannons were made of bronze, and early Spanish cannons are wonderful examples of metal-working skill in ornamentation.

* Courtesy of the National Tube Co.

But this was too expensive a material for gun barrels, and the need for cheaper material brought out the earliest application of wrought iron for tubes.

First Methods of Welding—In the early history of wrought iron tubes, the only known method consisted in bending an iron plate or strip to form a "skelp," and the edges were welded together piecemeal by a smith hammering the red hot metal over a rod or mandrel. A rather expensive and tedious process.

In 1812 an Englishman named Osborn patented machinery for "welding and making barrels of firearms and other cylindrical articles."

About the time of Osborn's invention for tube welding machinery another Englishman was perfecting his process of making coal gas for lighting purposes.

Iron tubes (gas tight) for this purpose were essential, and and the inventor of gas lighting (Murdock) first collected and used old gun barrels (of which there was an abundant supply at the close of the various European wars), screwing the barrels together into a continuous tube to convey the gas.

(Parenthetically, it may be said, some pessimists have stated that modern economists have reversed Murdoch's methods, and made gun barrels for remote markets from gas pipe)!

The extension of gas lighting was very rapid, and the necessity for production of iron tubes with greater facility and less cost became apparent.

Altitudes and Atmospheric Pressures of Gas Fields in the United States—The following table, from the United States Geological Survey, gives the altitudes, together with the average atmospheric pressure, in or near the different gas fields in the United States.

TABLE No. 4

TOWN	FEET ABOVE SEA LEVEL	AVERAGE ATMOSPHERIC PRESSURE	TOWN	FEET ABOVE SEA LEVEL	AVERAGE ATMOSPHERIC PRESSURE
Ashtabula, O.	688	14.33	Johnstown, Pa.	1184	14.07
Arkansas City, Kas.	1064	14.13	Joplin, Mo.	1018	14.16
Astoria, Ore.	50	14.67	Kansas City, Mo.	748	14.30
Alliance, O.	1083	14.12	Lexington, Ky.	975	14.17
Bradford, Pa.	1464	13.92	Los Angeles, Cal.	265	14.56
Batavia, N. Y.	895	14.22	Laredo, Tex.	806	14.26
Baldwinsville, N. Y.	390	14.49	Lima, O.	859	14.24
Beaumont, Tex.	26	14.69	Little Rock, Ark.	263	14.56
Boulder, Col.	5308	12.34	Muncie, Ind.	948	14.19
Bakersfield, Cal.	432	14.47	Mobile, Ala.	69	14.66
Bowling Green, Ky.	466	14.45	Marion, O.	979	14.17
Buffalo, N. Y.	588	14.38	Muskogee, Okla.	599	14.38
Birmingham, Ala.	596	14.38	Pittsburgh, Pa.	745	14.30
Charleston, W. Va.	603	14.37	Parkersburg, W. Va.	574	14.39
Chanute, Kas.	910	14.21	Port Huron, Mich.	633	14.36
Cincinnati, O.	501	14.43	Pierre, S. D.	1438	13.93
Corning, N. Y.	942	14.19	Pueblo, Col.	4669	12.72
Cleveland, O.	583	14.38	Robinson, Ill.	508	14.43
Columbus, O.	748	14.30	Red Bluff, Cal.	307	14.53
Corsicanna, Tex.	427	14.47	Raton, N. M.	6620	11.79
Claremore, Okla.	604	14.37	Roystone, Pa.	1465	13.92
Dallas, Tex.	466	14.45	Silver Creek, N. Y.	623	14.36
Dunkirk, N. Y.	598	14.38	Shreveport, La.	198	14.59
Des Moines, Ia.	800	14.27	San Antonio, Tex.	683	14.37
Erie, Pa.	686	14.33	Salt Lake City, Utah	4228	12.73
Evanston, Wyo.	6835	11.69	Santa Anna, Cal.	137	14.63
Fairmont, W. Va.	888	14.22	Tulsa, Okla.	701	14.32
Fort Worth, Tex.	623	14.36	Texarkana, Tex.	303	14.54
Fort Scott, Ark.	467	14.45	Trinidad, Col.	5820	12.12
Huntington, W. Va.	566	14.39	Toledo, O.	583	14.39
Huntsville, Ala.	612	14.37	Vincennes, Ind.	431	14.47
Hot Springs, Ark.	718	14.31	Warren, Pa.	1200	14.06
Henrietta, Tex.	915	14.21	Wheeling, W. Va.	637	14.36
Indianapolis, Ind.	709	14.32			

TABLE No. 5

Temperature Averages of Various Gas Fields and Cities Using Natural Gas

City	Average Annual Temperature	Average Daily Minimum in Winter	Average Daily Maximum in Summer	Average Humidity (%)
Astoria, Ore	51	..	..	..
Abilene, Tex	64	35	91	64
Buffalo, N. Y	47	20	75	73
Birmingham, Ala	64	38	90	..
Beaumont, Tex	69	..	..	..
Bakersfield, Cal	66	..	..	..
Cumberland, Md	51	22	86	..
Cleveland, Ohio	49	22	77	73
Columbus, Ohio	52	24	83	73
Cincinnati, Ohio	55	27	84	69
Corpus Christi, Tex	70	51	86	82
Charleston, W. Va	58	..	..	..
Chanute, Kan	56	..	..	..
Carlsbad, N. M	63	..	..	..
Des Moines, Ia	49	14	83	72
Dallas, Tex	65	33	94	..
Detroit, Mich	48	20	79	75
Erie, Pa	47	22	76	76
Fairmont, W. Va	54	..	..	..
Ft. Smith, Ark	61	31	90	70
Ft. Scott, Kan	56	..	..	..
Hot Springs, Ark	62	..	..	..
Henrietta, Tex	63	..	..	..
Huntington, W. Va	54	..	..	..
Indianapolis, Ind	55	23	84	70
Jamestown, N. Y	47	18	78	..
Johnstown, Pa	51	..	..	..
Joplin, Mo	57	..	..	..
Kansas City, Mo	54	23	85	70
Lexington, Ky	55	28	84	69
Laramie, Wyo	40	10	75	60
Los Angeles, Cal	62	45	82	71
Louisville, Ky	57	29	86	67
Little Rock, Ark	62	35	89	72
Lima, Ohio	50	..	..	..
Marion, Ohio	51	19	86	..
Mobile, Ala	67	45	89	81
Nashville, Tenn	59	32	87	71
Muskogee, Okla	60	..	..	..
Pittsburgh, Pa	53	25	83	72
Portsmouth, Ohio	56	24	87	..
Pueblo, Colo	52	17	87	48

TABLE No. 6

Temperature Averages of Various Gas Fields and Cities Using Natural Gas—Continued

City	Average Annual Temperature	Average Daily Minimum in Winter	Average Daily Maximum in Summer	Average Humidity (%)
Port Huron, Mich..	46	18	76	77
Pierre, S. D........	47	10	85	64
Parkersburg, W.Va.	54	26	84	76
Red Bluff, Cal.....	63	39	93	57
San Francisco, Cal.	56	46	65	80
Shreveport, La.....	66	40	92	73
San Antonio, Tex..	69	44	93	67
Toledo, Ohio.......	50	21	79	74
Texarkana, Ark....	64	..	..	..
Tulsa, Okla........	60	..	..	..
Wheeling, W. Va...	56	..	..	..
Warren, Pa.........	47	..	..	..
Wichita, Kan......	56	24	88	68

Atmospheric Pressure—The average pressure at the sea level is 30.00 inches of mercury, equal to 14.72 pounds per square inch. Under favorable conditions above the sea level the pressure decreases as shown by the following table.

TABLE No. 7

Altitude Above Sea Level. Feet	Barometric Pressure	
	Lb. per Sq. In.	Inches of Mercury
0	14.72	30.00
500	14.45	29.45
1000	14.19	28.92
1500	13.92	28.37
2000	13.65	27.82
2500	13.39	27.28
3000	13.12	26.73
4000	12.69	25.86
5000	12.22	24.90
6000	11.75	23.94

2.0375 inches of mercury or 27.71 inches of water at 60 deg. fahr. equal one pound. Mercury is 13.60 times heavier than water.

In higher altitudes there is an increase in the number of feet in elevation per inch of mercury.

Table Showing the Weight per 1000 Cu. Ft. of Air and Natural Gas of 0.6 Specific Gravity at Different Temperatures and at a Pressure of 14.65 Lb. per Sq. In. Absolute Corresponding to 4 Ounces Above 14.4 Lb. Atmospheric Pressure.

TABLE No. 8

Temperature Deg. Fahr.	Weight in Pounds		Temperature Deg. Fahr.	Weight in Pounds	
	1000 Cu. Ft. of Gas of 0.6 Sp. Gr.	1000 Cu. Ft. of Air		1000 Cu. Ft. of Gas of 0.6 Sp. Gr.	1000 Cu. F. of Air
0	51.69	86.15	110	41.70	69.50
10	50.58	84.31	120	40.98	68.30
20	49.53	82.55	130	40.28	67.14
32	48.32	80.54	140	39.61	66.02
40	47.55	79.25	150	38.96	64.94
50	46.61	77.69	160	38.33	63.89
60	45.71	76.19	170	37.72	62.87
70	44.85	74.75	180	37.13	61.89
80	44.02	73.37	190	36.56	60.94
90	43.22	72.03	200	36.00	60.01
100	42.44	70.74	212	35.36	58.94

Production of Natural Gas*—The following tables give, by States, the total value in thousands of dollars of the natural gas produced in the entire country from 1884 to 1913, inclusive:

TABLE No. 9

PRODUCTION

State	1886	1887	1888	1889	1890	1891	1892
Pennsylvania	$ 9,000	$ 13,749	$ 19,282	$ 11,593	$ 9,551	$ 7,834	$ 7,376
New York	210	333	332	530	552	280	216
Ohio	400	1,000	1,500	5,215	4,684	3,076	2,136
West Virginia	60	120	120	12	5	35	70
Illinois	4	...	...	10	6	6	12
Indiana	300	600	1,320	2,075	2,302	3,942	4,716
Kansas	6	...	...	15	12	5	40
Missouri	...	...	...	35	10	1	3
California	...	...	...	12	33	30	55
Kentucky and Tennessee	...	...	...	2	30	38	43
Texas and Alabama	...	...	...	1	...	...	†
Arkansas and Wyoming	...	...	...	†	...	†	†
Other	32	15	75	1,600	1,606	250	200
Total	10,012	15,817	22,629	21,107	18,792	15,500	14,870

In 1884 Pennsylvania produced 1,100,000; other states 360,000; totaling 1,460,000.
In 1885 Pennsylvania produced 4,500,000; other states 357,200; totaling 4,857,200.

* Hill, B., "The Production of Natural Gas in 1913."
† Less than one thousand dollars.

PRODUCTION—*Continued*

State	1893	1894	1895	1896	1897	1898	1899
Pennsylvania	$ 6,488	$ 6,279	$ 5,852	$ 5,528	$ 6,242	$ 6,806	$ 8,337
New York	210	249	241	256	200	229	294
Ohio	1,510	1,276	1,255	1,172	1,171	1,488	1,866
West Virginia	123	395	100	640	912	1,334	2,335
Illinois	14	15	7	6	5	2	2
Indiana	5,718	5,437	5,203	5,043	5,009	5,060	6,680
Kansas	50	86	112	124	105	174	332
Missouri	2	4	3	1	†	†	†
California	62	60	55	55	50	65	86
Kentucky and Tennessee	68	89	98	99	90	103	125
Texas and Alabama	†	†	†	......	......	†	8
Arkansas and Wyoming	†	†	†	†	†	......	......
Utah	†	†	20	20	15	7	......
Colorado	......	12	7	4	4	3	1
South Dakota	......	......	......	......	......	......	3
Indian Territory and Oklahoma	......	......	......	......	......	......	......
Louisiana	......	......	......	......	......	......	......
Other	100	50	50	50	20	20	......
Total	14,346	13,954	13,006	13,002	13,826	15,296	20,074

† Less then one thousand dollars.

PRODUCTION—(*Continued*)

State	1900	1901	1902	1903	1904	1905	1906
Pennsylvania	$ 10,215	$ 12,688	$ 14,352	$ 16,182	$ 18,139	$ 19,197	$ 18,558
New York	335	293	346	493	522	623	672
Ohio	2,178	2,147	2,355	4,479	5,315	5,721	7,145
West Virginia	2,959	3,954	5,390	6,882	8,114	10,075	13,735
Illinois	1	1	1	3	4	7	87
Indiana	7,254	6,954	7,081	6,098	4,342	3,094	1,750
Kansas	356	659	824	1,123	1,517	2,261	4,010
Missouri	†	1	2	7	6	7	7
California	79	67	120	104	114	133	134
Alabama							
Texas	286	270	365	390	322	14	150
Louisiana						1	
Kentucky	20	18	14	13	14	237	287
Tennessee	......	......	......	2	6	†	†
Arkansas and Wyoming	......	......	......	......	......	21	34
Colorado	1	1	1	14	14	20	22
South Dakota	9	7	10	10	12	15	15
Oklahoma	......	......	......	......	......	130	259
North Dakota	......	......	†	1	49	......	......
Oregon	......	......	......	......	......	......	......
Iowa	......	......	......	......	......	......	......
Total	23,698	27,066	30,867	35,807	38,496	41,562	46,873

† Less then one thousand dollars.

PRODUCTION—*Continued*

State	1907	1908	1909	1910
Pennsylvania	$ 18,844	$ 19,104	$ 20,475	$ 21,057
New York	766	959	1,222	1,678
Ohio	8,718	8,244	9,966	8,626
West Virginia	16,670	14,837	17,538	23,816
Illinois	143	446	644	613
Indiana	1,572	1,312	1,616	1,473
Kansas	6,198	7,691	8,293	7,755
Missouri	17	22	10	12
California	168	307	446	476
Texas				
Alabama	178	236	453	956
Louisiana				
Kentucky	380	424	485	456
Tennessee	†	†	†	†
Arkansas and Wyoming	126	164	226	301
Colorado	......	......		
Oklahoma	417	860	1,806	3,490
South Dakota	19	24	16	31
North Dakota	†	2	3	7
Oregon	†	†	†	......
Iowa	......	†	†	†
Michigan	......	......	†	†
Total	54,222	54,640	63,206	70,756

† Less than one thousand dollars.

PRODUCTION—*Continued*

State	1911	1912	1913	1914	1915	1916	1917
Pennsylvania	$ 18,520	$ 18,539	$ 21,695	$ 20,839	$ 21,139	$ 24,344	$ 28,716
New York	1,418	2,343	2,425	2,600	2,335	2,524	2,499
Ohio	9,367	11,891	10,521	14,667	17,391	15,601	18,434
West Virginia	28,435	33,324	34,164	35,076	36,424	47,603	57,389
Illinois	687	616	574	437	350	396	479
Indiana	1,192	1,014	843	755	695	503	453
Kansas	4,854	4,264	3,288	3,340	4,037	4,855	5,701
Missouri	10	11	6	5	7	17	8
California	800	1,134	1,883	2,910	4,069	5,440	6,816
Kentucky	407	522	509	490	614	752	580
Tennessee	†	†	†	†	†	1	2
Texas	1,014	1,405	2,073	2,469	2,593	3,143	3,192
Louisiana	858	1,747	2,119	2,227	2,163	2,660	3,262
Alabama							
South Dakota	16	30	31	27	36	31	25
North Dakota	5						
Wyoming					59	86	144
Colorado	295	309	269	214			
Arkansas	....	....	....	....	193	241	315
Oklahoma	6,731	7,406	7,436	8,050	9,195	11,983	13,984
Iowa	†	†	†	†	†	†	†
Michigan	1	1	1	1	1	†	1
Montana	....	....	....	....	2	38	81
Total	74,621	84,563	87,846	94,115	101,312	120,227	142,089

† Less than one thousand dollars.

TABLE No. 10—NATURAL GAS PRODUCED AND CONSUMED IN THE UNITED STATES IN 1916 AND 1917.

Prepared under the supervision of J. D. Northrop

PRODUCTION

State	1916 Volume (M Cubic Feet)	1916 Value	1916 Average Price per M.	1917 Volume (M Cubic Feet)	1917 Value	1917 Average Price Per M
West Virginia	299,318,907	$47,603,396	15.90	308,617,101	$57,389,161	18.60
Oklahoma	123,517,358	12,014,706	9.73	137,384,154	13,984,656	10.18
Pennsylvania	130,483,705	24,513,119	18.78	133,397,206	28,716,492	21.53
Ohio	69,888,070	15,601,144	22.32	68,917,231	18,434,814	26.75
California	31,643,266	5,440,277	17.19	49,427,331	6,816,524	13.79
Louisiana	32,080,975	2,660,445	8.29	31,286,476	3,262,987	10.43
Kansas	31,710,438	4,855,389	15.31	24,438,848	5,701,436	23.33
Texas	15,809,579	3,143,871	19.89	17,047,292	3,192,625	18.73
New York	8,035,632	2,355,320	29.31	8,371,747	2,499,303	29.85
Arkansas	2,387,935	210,964	8.83	5,609,484	315,612	5.63
Illinois	3,533,701	396,357	11.22	4,439,016	479,072	10.79
Kentucky	2,106,542	752,635	35.73	2,802,079	580,380	20.71
Indiana	1,715,499	503,373	29.34	1,711,454	453,310	26.49
Wyoming Colorado	575,044	86,077	14.97	1,223,136	144,425	11.81
Montana South Dakota	213,315	38,855	18.21	334,421	81,406	24.34
Alabama North Dakota	77,478	31,573	40.75	59,666	25,213	42.26
Missouri	69,236	17,594	25.41	31,425	8,230	26.19
Tennessee	2,000	1,150	57.50	10,900	2,450	22.48
Michigan	1,298	948	73.04	1,184	1,013	85.55
Iowa	275	275	100.00	225	225	100.00
Total	753,170,253	120,227,468	15.96	795,110,376	142,089,334	17.87

TABLE No. 11—NATURAL GAS PRODUCED AND CONSUMED IN THE UNITED STATES IN 1916 AND 1917

Prepared under the supervision of J. D. Northrop

CONSUMPTION

State	1916 Volume (M Cubic Feet)	1916 Value	1916 Average Price Per M	1917 Volume (M Cubic Feet)	1917 Value	1917 Average Price Per M
West Virginia	105,104,008	$ 8,610,084	8.19	a115,488,192	$10,558,612	9.14
Oklahoma	b93,704,221	7,062,142	7.54	b122,177,676	10,900,827	8.92
Pennsylvania	201,460,893	35,015,695	17.38	202,259,498	40,773,689	20.16
Ohio	169,480,011	37,394,410	22.06	165,782,369	44,742,782	26.99
California	31,643,266	5,440,277	17.19	49,427,331	6,816,524	13.79
Louisiana	c32,080,975	2,660,445	8.29	c31,286,476	3,262,987	10.43
Kansas	d60,564,112	9,731,518	16.07	d37,962,857	8,463,767	22.29
Texas	15,809,579	3,143,871	19.89	17,901,637	3,433,123	19.18
New York	20,594,123	6,230,826	30.26	22,466,848	6,912,540	30.77
Arkansas	f 3,347,398	287,399	8.59	f 6,437,608	396,612	6.16
Illinois	e3,533,701	396,357	11.22	e4,439,016	479,072	10.79
Kentucky	9,887,956	2,331,687	23.58	12,053,445	3,114,402	25.84
Indiana	5,021,364	1,746,285	34.78	5,766,466	1,971,435	34.19
Wyoming, Colorado	575,044	86,077	14.97	1,223,136	144,425	11.81
Montana	213,315	38,855	18.21	334,421	81,406	24.34
South Dakota, Alabama, North Dakota	77,478	31,573	40.75	59,666	25,213	42.26
Missouri	69,236	17,594	25.41	31,425	8,230	26.19
Tennessee	2,000	1,150	57.50	10,900	2,450	422.48
Michigan	1,298	948	73.04	1,184	1,013	85.55
Iowa	275	275	100.00	225	225	100.00
Total	753,170,253	120,227,468	15.96	795,110,376	142,089,334	17.87

a Includes gas piped from West Virginia and consumed in Maryland.
b Includes gas piped from Oklahoma and consumed in Missouri.
c Includes gas piped from Louisiana and consumed in Arkansas and Texas.
d Includes gas piped from Kansas and consumed in Missouri.
e Includes gas piped from Illinois and consumed in Indiana.
Includes gas piped from Oklahoma.

PART TWO

PROPERTIES OF GASES

DESCRIPTION OF VARIOUS GASES—THEIR PROPERTIES AND ANALYSES.

Air—Air is a mechanical mixture of oxygen and nitrogen, with about 1 per cent. by volume of argon. At 29.85 barometer and 60 deg. fahr., one cubic foot of pure dry air will weigh .07606 lb. and 1000 cubic feet will weigh 76.06 lb.

While the composition of air varies, the following is taken from *Bulletin U. S. Geological Survey No. 330.*

By Volume				By Weight		
N.	O.	Ar.		N.	O.	Ar.
78.122	20.941	0.937	—	75.539	23.024	1.437

Air expands 1/ 491.2 of its volume at 32 deg. fahr. for every increase of 1 deg. fahr., and its volume varies inversely as the pressure.

Hydrogen—Hydrogen Gas H_2 is colorless, odorless, non-poisonous, and the lightest substance known. Hydrogen in a commercial gas makes it lighter, increases the heating value, the amount of air required for combustion, and the heat loss in the products of combustion. It is very combustible, and uniting with oxygen, burns with a pale blue, nearly non-luminous flame, producing water in the form of water vapor. Hydrogen is always a desirable constituent on account of its high calorific power and its avidity for combustion. It will not stand much compression without danger of self-ignition. Its high heating value is 324 B. t. u. per cubic foot at 60 deg. fahr. and 29.85 inches of mercury.*

*This basis of measurement, 60 deg. fahr. and 29.85 inches of mercury (14.65 lb. absolute) is adhered to throughout unless otherwise stated.

Olefiant Gas—This is sometimes called ethylene, and is the main illuminating constituent of coal gas. It has a chemical formula of $C_2 H_4$. It is evolved when oil or coal is heated. It has a very high calorific power, 1578 gross B. t. u. per cubic foot, and possesses fourteen times the luminosity of marsh gas. It is colorless, odorless, and burns with a highly luminous flame.

Methane—In natural gas the chief member of the marsh gas series is methane or marsh gas itself, having the formula CH_4, and a composition of 25.03 per cent. hydrogen and 74.97 per cent. carbon by weight. The name marsh gas comes from the fact that it is frequently produced by the decay of plants in swamps and the bottom of rivers. When pure it is a colorless, odorless gas, lighter than air and having a specific gravity of .553. Its gross heating value is 1003 B. t. u. per cubic foot at 60 deg. fahr. and 29.85 inches of mercury (14.65 pounds per square inch absolute.)

Ethane—Ethane C_2H_6, the next member of the marsh gas series, is sometimes found in considerable quantities in natural gas. It greatly resembles methane in its general properties, being a better fuel and burning with a slightly luminous flame, which makes it a better illuminant than methane. The heat value per cubic foot is 1754 B. t. u.

Ethane contains 79.96 per cent. of carbon and 20.04 per cent. of hydrogen by weight.

Carbonic Oxide—This is also known as carbon monoxide, CO, and is one of the most important constituents of producer gas. It is odorless, colorless, practically insoluble in water, very poisonous and burns with a distinctive pale blue flame. Its high or gross heating value is 322 B. t. u. per cu. ft.

Carbon Dioxide—It is called carbonic acid and carbonic anhydride, CO_2. It is colorless, odorless, soluble in water,

non-combustible, and is formed by the combustion of carbon and oxygen at high temperature.

Oxygen O_2—This is tasteless, odorless, invisible and slightly heavier than air. It exists in a free state in the atmosphere and in combination in the ocean. It forms about one-fifth of the former and eight-ninths of the latter.

Nitrogen N_2—This is a colorless, odorless, non-combustible gas and is always present in large quantity in gases produced by incomplete combustion. It forms four-fifths of the volume of air.

Hydrocarbons—The number of known hydrocarbons is nearly two hundred. The term is applied to all compounds consisting only of hydrogen and carbon. These compounds exist in gaseous, vaporous, liquid and solid states. Low temperatures are conducive to the formation of the easily condensed, tarry compounds, while with high temperatures, the yield of hydrogen and permanent gases is greatly increased.

Illuminants—In gas analysis part of the constituents are sometimes mentioned as illuminants, the term illuminant signifying a substance that makes the gas flame luminous, and olefiant gas is usually included with this.

Natural Gas—The principal constituent is marsh gas. The exact composition varies with the different districts.

Oil Gas—This gas is made from oil, generally by allowing the liquid to flow slowly, and in a thin, continuous stream, through a highly heated pipe or retort where the oil is vaporized. This usually evolves hydrogen, marsh gas, and olefiant gas mixed with vapor which will usually be condensed in the scrubbing apparatus.

Coal Gas—It is also called "bench" or "illuminating" gas. The former refers to the benches which hold the retort

while the latter is dubious, since several other gases are distributed as illuminating gas. Coal gas is made by destructive distillation of bituminous coal in externally heated air-tight retorts. The resulting gas is withdrawn by an exhauster and the residual coke is removed periodically.

Water Gas—This is produced by the decomposition of steam acting on incandescent carbon. On account of the large amount of carbon monoxide present the gas is very poisonous.

Coke Oven Gas—By-Product or Coke Oven Gas, as it is some times called, is a by-product of the destructive or dry distillation of coal for the formation of coke. This was formerly done in a type of kiln known as a bee-hive coke oven, in which all of the by-products were lost. With the present day methods, these by-products are saved and utilized.

The type of oven most used to-day, is known as a by-product oven, of which there are various types, consisting generally of several retorts, either horizontal, vertical or chamber, made of fire brick, placed side by side in battery form. There are generally several hundred of these retorts, varying with the size of the plant, each retort being capable of containing from six to twelve tons of coal. Each ton of coal is capable of producing from 6,500 to 12,000 cubic feet of gas, depending on the kind and quality of coal and the type of oven used. The walls of the retorts contain flues which are heated by a gas flame.

Preheating of the air and gas is effected by a system of regenerators, so that no heat is wasted by the escape of hot gases or products of combustion. The charging and discharging is effected by mechanical means. The gas given off contains some tar in a vaporous form, also naphthalene, benzol, cyanogen and suplhates of ammonium in small quantities.

The capacity of the plants vary with the size. A plant of about five hundred and fifty ovens will produce approximately sixty-five million cubic feet of gas daily, while a plant of three hundred ovens will produce approximately twenty-five million cubic feet of gas daily. This gas is generally piped to a gas holder or gasometer, which acts as a storage and also a cushion on the line.

Boosters, either of the positive type or of the Turbo type, take the gas and pump it into mains leading to the various buildings, where it is distributed to the various furnaces, ovens, etc., where it is consumed. The pressure maintained by the booster varies from 5 lb. to about 8 lb. This is done for the reason that where the gas is utilized, a pressure of from ½ to 1½ lb. is the most desirable to use.

In all modern coke oven gas plants the gas is purified, *i. e.*, tar, benzol and other condensable properties are removed by cooling or by absorption in straw oil, leaving the gas as free from impurities as any other gas. In this state it is an easy matter to measure accurately.

Where the gas is purified the steam-jacketed meter or flange is not necessary.

The specific gravity of the coke oven gas varies from 0.36 to 0.40, the average being 0.38.

In measuring "crude" coke oven gas the meters should be steam jacketed and a temperature of at least 120 deg. fahr. should be maintained. This will prevent the depositing of tar and naphthalene on the orifice.

The mains should be so arranged that steam may be blown through them, at about 150 foot intervals, to remove any naphthalene deposits which may occur. This need is, however, eliminated to some extent if the gas is first passed through a benzol plant, in which case the naphthalene is mostly removed. The line should also be provided with drips for draining off any condensed naphthalene.

The meters used should be of the Orifice type and should be steam jacketed for maintaining a temperature of at least 120 deg. fahr. This will prevent the depositing of naphthalene and will also prevent the tar in the gas from clogging the meter.

The gas where used under boilers, etc., should be used with a burner similar to a natural gas burner, *i. e.*, one with an air mixer. These burners can be made of pipe and should extend through a brick chamber, which opens into a larger combustion space containing checker-work. This combustion space will become very hot, causing the bricks to glow. The flame will be colorless.

The gas is also used in soaking pits, billet heating furnaces, spike factory work, bolt and nut factory work, open-hearth, etc. In all cases to get the best results, the gas should be preheated. This can be done by mixing with the air from the checker work. In open-hearth practice, where it is desirable to have some color to the flame, a small quantity of tar can be forced into the burner under pressure. This will produce the desired result.

In figuring for credits, the B. t. u. of coal is generally taken as 10,500; this is, however, a variable quantity, depending on the type of coal previously used, 1 lb. of tar is equivalent to 15.3 lbs. of coal of this grade. The B. t. u. of the gas varies from about 350 to 640. For the sake of accuracy it is desirable to take the values every day.

All gas should be metered to each department, thus giving a positive measure of what each department is using. This should then be credited to the coke plant at the rate of 40,000 cubic feet of gas, being equivalent to 1 gross ton of Illinois coal. The price of coal in the district will then govern the price per 1000 cubic feet of gas.

Where used under boilers the number of cubic feet of gas equivalent to 1 ton of coal can be determined by the following formula: Cubic feet of gas equals

$$\frac{\text{B. t. u. in 1 gross ton of coal}}{\text{B. t. u. in 1 cu. ft. gas (calorimeter)}} \times \frac{\text{Efficiency of Boiler with coal}}{\text{Efficiency of Boiler with gas}}$$

For example: One ton of coal, 2,200 lb., with 10,500 B. t. u. per lb., the calorimeter test showing the gas to have 507 B. t. u. with coal, the efficiency of the boiler is 60 per cent. while with gas the efficiency is 65 per cent, then by the formula

$$\frac{10{,}500 \times 2200}{507} \times \frac{60}{65} = 43{,}000 \text{ cu. ft. of gas being equi-}$$

valent to one ton of coal. Assume the coal to be $1.90 per ton, then the value of the gas per 1000 cubic feet is 1.90 / 43 = 4.4 cents.

Natural Gas Analysis—To treat this subject fully would require a volume in itself. Therefore we refer the reader to Hempel's *Gas Analysis*, or Stone's *Practical Testing of Gas and Gas Meters*.

In general the analysis of gas consists in absorbing the constituents one by one, in appropriate reagents, and measuring the decrease of volume caused by such absorption.

Certain substances, such as hydrogen and methane, cannot readily be treated in this manner, and these are determined by exploding with oxygen and determining the products of the explosion or the diminution in volume of the original mixture.

To Obtain Sample of Gas—The sample tube commonly used is a glass bulb 1¾ inches in diameter and 2¾ inches long, with the ends drawn out into capillary tubes, and terminating in two short ends ¼-inch in diameter. One end is connected to the gas supply by means of a piece of rubber tubing; the gas is turned on, and is lighted at the other end of the sample tube. If the flame is not over 1½ inches long there will be no danger of melting the glass, and the bulb may be purged of air by continuing the combustion for a reasonable period. As a rule, one-half to three-quarters of an hour will be ample. Great care should be used to close

TABLE No. 13—PROPERTIES OF GASES

	S. G. Liquid	Be. G. Liquid	Lb. per Gal. Liquid	S. G. Gas	Lb. per M. Cu. Ft. Gas	Combustion Ratios: Cont.	C O_2	O_2 Used	$R\left(\frac{Cont}{CO_2}\right)$	$R'\left(\frac{S.G.}{R}\right)$
Water..........	1.00	10	8.35	....	....	....	....	....	....	....
Air............	....	....	....	1.0	80.72	....	....	....	....	....
Methane........	.411–160°F.	....	3.36	.56	45.20	2.0	1.0	2.0	2.00	0.28
Ethane.........	.446– 0°F.	....	3.72	1.04	83.95	2.5	2.0	3.5	1.25	.832
Propane........	.536 0°F.	130	4.48	1.52	122.69	3.0	3.0	5.0	1.00	1.52
Butane.........	.60	103	5.01	2.01	162.25	3.5	4.0	6.5	0.875	2.18
Petane.........	.626	94	5.23	2.49	201.00	4.0	5.0	8.0	0.80	3.12
Hexane.........	.663	81	5.54	2.98	240.55	4.5	6.0	9.5	0.75	3.97
Heptane........	.688	73	5.75	3.46	279.29	5.0	7.0	11.0	0.71	4.87

TABLE No. 14

EXCESS WEIGHT ABOVE DRY GAS (S. G. 0.56) FOR VARIOUS S. G. LB. PER M. CU. FT.

Specific Gravity	Decimals: .00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.5	....	....	....	....	....	....	....	.807	1.614	2.421
.6	3.228	4.036	4.84	5.65	6.46	7.26	8.07	8.88	9.68	10.49
.7	11.29	12.10	12.91	13.72	14.53	15.33	16.14	16.85	17.75	18.56
.8	19.36	20.17	20.98	21.79	22.60	23.40	24.21	25.02	25.82	26.63
.9	27.43	28.24	29.05	29.86	30.67	31.47	32.28	33.09	33.89	34.70
1.0	35.50	36.31	37.12	37.93	38.74	39.54	40.36	41.16	41.96	42.77
1.1	43.57	44.38	45.20	46.00	46.81	47.61	48.43	49.23	50.03	50.84
1.2	51.64	52.45	53.27	54.07	54.88	55.68	56.50	57.30	58.10	58.91
1.3	59.71	60.52	61.34	62.14	62.95	63.75	64.57	65.37	66.17	66.98

TABLE No. 15—COMMERCIAL GASES*

(*By Wyer*)

Name	H	CH_4	C_2H_4	N	CO	O	CO_2	B. t. u. in 1 Cu. Ft. Explosive Mixture	B. t. u. Cu. Ft.	O. Required for Combustion	Air for Combustion
Natural gas (Pittsburgh)	3.0	92.0	3.0	2.0	....	....	....	91.0	978.0	1.94	9.73
Oil Gas	32.0	48.0	16.5	3.0	....	0.5	....	93.0	846.0	1.61	8.07
Coal or bench gas	46.0	40.0	5.0	2.0	6.0	0.5	0.5	91.7	646.0	1.21	6.05
Coke-oven gas	50.0	36.0	4.0	2.0	6.0	0.5	1.5	91.0	603.0	1.12	5.60
Carbureted water gas	40.0	25.0	8.5	4.0	19.0	0.5	3.0	92.0	575.0	1.05	5.25
Water gas	48.0	2.0	....	5.5	38.0	0.5	6.0	88.0	295.0	0.47	2.35
Producer-gas from hard coal	20.0	....	....	49.5	25.0	0.5	5.0	68.0	144.0	0.22	1.12
Producer-gas from soft coal	10.0	3.0	0.5	58.0	23.0	0.5	5.0	65.5	144.0	0.24	1.20
Producer-gas from coke	10.0	....	....	56.0	29.0	0.5	4.5	63.0	125.0	0.19	0.98
Blast-furnace gas	1.0	....	....	60.0	27.5	....	11.5	....	91.0	1.43	.72

TABLE No. 16—COMBUSTIBLE GAS MIXTURES*

(*By Wyer*)

Name of Gas	Explosive Mixture Air to 1 Volume Gas
Hydrogen	2.4
Carbon monoxide	2.4
Marsh gas	9.6
Olefiant gas	14.4
Acetylene	12.0
Coal gas	5.7

*Note—Producer Gas and Gas Producers, by S. S. Wyer.

the ends of the glass bulb to prevent leakage or allow the air to mix with the gas on the inside of the tube. The safest way to do this is with a blowpipe and a pair of pliers, melting the ends of the glass tubes and squeezing them shut, thus making a seal of glass.

In making the seal, turn the gas partly off until the flame is about ¼-inch long; then, with the blowpipe, seal the capillary nearest the outlet. With the gas pressure still on, seal the capillary at the other end.

Great care should be used in packing the bulb for shipment or carrying. The tube if properly packed can be shipped by express to any laboratory for analysis.

Candle Power—A standard candle power is the illumination obtained from the flame of a spermaceti candle burning at the rate of two grains per minute. Sixteen candle power is the illumination given off from sixteen such candles. In making candle power tests, reliance must be placed on the human eyesight, which is variable and uncertain. Conditions of atmosphere and temperature affect the standard candle differently, so that the tests vary. In judging the quality of gas this standard is not as satisfactory as by the B. t. u. standard, which is a positive criterion of the quality of natural gas. This test for heat is scientific, mechanical and accurate.

British Thermal Units (B. t. u.)—The B. t. u. standard of determining the quality of natural gas is universally recognized by the natural gas fraternity.

British Heat Unit, or British Thermal Unit, indicates the heat necessary to raise the temperature of one pound of pure water at 39 deg. fahr. through one degree.

There are two methods employed to ascertain the B. t. u. of any gas. One is to use the calorimeter, and the other is to compute it from the gas analysis. In the latter case, it is

necessary to have the B. t. u.'s of the different gases found in the analysis. These are given on page 132.

B. t. u.'s figured from candle power are valueless.

There are several calorimeters, namely, Hinman-Junker, Simmance-Abady, Sargent, Doherty, and the Boys.

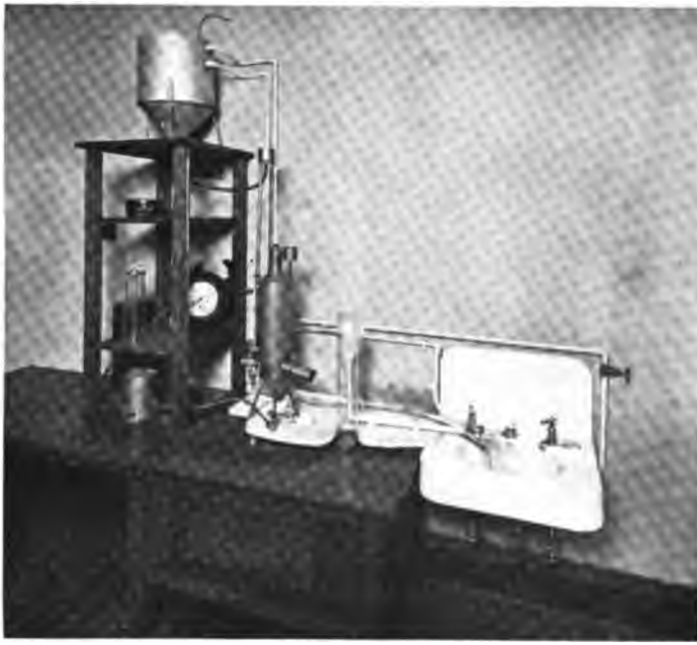


Fig. 25—A CONVENIENT CALORIMETER INSTALLATION

Calorimeters for Determining the B. t. u. of Natural Gas—A calorimeter is an apparatus to determine the number of B. t. u. in one cubic foot of gas. The complete apparatus consists of a one-tenth foot drum wet meter, wet governor, calorimeter with three thermometers, small graduate, rubber tubing, weighing balance, copper water buckets, or, in place of the last two items, a large graduate.

Fig. 26—THE HINMAN-JUNKER CALORIMETER
Used in Determining the B. t. u. of Either Artificial or Natural Gas

No instructions for use o the calorimeter are given here on account of the limited space available. Complete instructions will be found in Circulars Number 48 and 65 and in Technologic Paper Number 36, published by the Bureau of Standards, Washington, D. C. Special reference should be made to pages 62 to 84 in Circular Number 48, new edition.

Specific Gravity—Specific gravity is the ratio between the density of a body and the density of some other body chosen as a standard. The specific gravity of solids and liquids is given in terms of water. In this case the specific gravity is the ratio between the mass of any volume of the substance and the mass of an equal volume of water.

In stating the specific gravities of gases, air is generally taken as a standard. It is very necessary to know the specific gravity of any gas when one is measuring gas by an orifice meter, using an orifice well-tester to determine the flow of a small gas well or the casinghead gas from an oil well or in testing a large capacity meter with the funnel-meter in the field. It is also of advantage in making preliminary tests as to the quality of casinghead gas.

Bunsen Effusion Method—This method is based upon the fact that the specific gravity of gases is in inverse ratio to the squares of the rates of effusion. For testing casinghead gas, etc., where an accuracy greater than 2 points in the second decimal place is not desired, the Bunsen effusion method is satisfactory and very simple. The apparatus is portable and the test can be run very quickly.

The apparatus shown in Fig. 27 is built on this principle.

Specific Gravity Apparatus—This is a very simple and convenient apparatus for ascertaining the specific gravity, or density of gases. It consists of a glass jar with a metal top into which fits a brass column having suspended from

its base a long graduated, glass tube, and at its top a cock and a ground joint socket, into which sets a socket holding a small glass tip closed in at the top with a very thin piece of platinum. In this platinum is a minute hole to permit the passage of gas or air at a very slow rate.

Fig. 27—SPECIFIC GRAVITY APPARATUS AND CARRYING CASE

To Operate a Specific Gravity Apparatus—The mode of operation is as follows:

The small glass tube carrying graduations should be placed in the center of the large glass jar while in an upright position.

The large glass jar should be filled with clear water to a little above the top graduation of the small glass tube. This tube should then be withdrawn so as to fill it with air. Prior to placing tube back in the water, shut off the cock on the standard. Place the platinum tip which is encased with glass and protected by a small metal tube in the top of the standard above the cock. Then open the three-way cock so that the air will pass through the small orifice in the platinum tip.

By use of stop watch, take the time in seconds required for the water level to raise from the 2 inch to the 8 inch graduation as etched on the inner glass tube. Repeat the operation of filling the inner tube with air, passing the air through the small orifice in platinum tip and timing same at least four or five times.

Then without the loss of any water in the large glass jar or without removing the platinum tip from the ground joint

on top of the standard above the cock, connect a common ⅜ rubber hose with the side opening at the three-way cock and allow the gas to pass downward through the inner glass tube while it is in the proper position immersed in the water. This will cause the gas to escape through the water from the bottom of the inner tube into the atmosphere.

Care should be taken that the gas is not turned on too much so that it will cause any water to be lost from the larger jar as the bubbles of gas break through the surface of the water.

This operation assures one of expelling all the air in the inner tube. After continuing this operation for two or three minutes, shut off the gas at the three-way cock and allow the gas in the tube to pass through the small orifice as described in the above paragraph.

Repeat the operation at least four or five times, taking the time required for the water level in the inner tube to rise from the 2 inch graduation to the 8 inch graduation, these being the same graduations as used when running the air test.

Average the time required for the air to pass through the small orifice and also, average the time required for the gas to pass through the small orifice, then substitute the figures in seconds for G and A as found in the formula below.

The specific gravity, air being one, is obtained by dividing the gas time squared by the air time squared.

Formula is— $\text{Specific Gravity} = \frac{G^2}{A^2} = \left(\frac{G}{A}\right)^2$

G = Time gas requires to pass through orifice.
A = Time air requires to pass through orifice.

While boring out the hole in the tip will shorten the time for each individual test it will also greatly increase the liability of error in the final results. The longer time it takes for each test, the more accurate the results.

It is good policy not to make any gravity tests during freezing weather, as the orifice in the tip is liable to become frosted, which would cause varying and inaccurate results.

This type of specific gravity apparatus is commonly condemned when the operator does not obtain consistent results. In one incident known to the author the results obtained varied from 0.62 to 0.68 specific gravity. Upon immersing the inner glass tube valve and tip under water, it showed several leaks around the joints which would make it impossible to obtain the correct gravity in a test or series of tests. No doubt the leaks had developed through hard usage.

Fig. 28—The new design inner tube used in Specific Gravity Outfit shown in Fig. 27, page 121.

To obtain accurate results the inner glass tube, valve and tip should have no leaks, however small. A considerable error is introduced if any water is lost from the cylinder between the gas determination and the air determination; serious errors are caused if the tip frosts up in cold weather or if moisture collects on the tip. It seems probable that with the majority of effusion meters an accuracy of about two in the second decimal place is secured.

With the outfit shown in Fig. 27 the bottle can be filled with water and carried from one well to another without any danger of losing a drop. This permits the taking of several gas tests at various wells after taking but one air test. An air test should be taken at the beginning of each series of gas tests.

In the following article will be found a full description of the new specific gravity apparatus designed by the Bureau of Standards, together with full instructions for its use. Since this article was written and the experiments were made by the Bureau of Standards, the manufacturer of the apparatus shown in Fig. 27 has brought out an im-

proved inner glass tube which without doubt greatly improves the accuracy of the instrument.

The new design of inner tube has the same contracted throats at top and bottom as found in the apparatus designed by the Bureau of Standards, and shown in Fig. 28.

At this writing no opportunity has been had to make comparative tests with the Edwards Gas Balance, but

Fig. 29—NEW DESIGN SPECIFIC GRAVITY APPARATUS.

enough is known from the practical working of the outfit, with the new design inner tube, to state that the improvement has greatly improved the accuracy of the old outfit.

For taking specific gravities of gas for meter testing in the field and where the result is not required in thousandths, the apparatus shown in Fig. 27 is well suited.

For coefficients where large volumes of gas are measured and consequently large sums of money are involved, it is best to use the apparatus shown in Fig. 29.

BUREAU OF STANDARDS EFFUSION SPECIFIC GRAVITY APPARATUS

From Technologic Paper No. 94, by Junius David Edwards, Assistant Chemist

With Alterations and Additions

"The determination of the specific gravity of gases, that is, their density, or weight, compared with air, is of very great importance for many purposes, both scientific and commercial.

Specific Gravity Balance—Its accurate determination, as for scientific purposes, is best made by means of the specific gravity balance. This method is fully explained and advised upon in Bureau of Standards Technologic Paper No. 89.

Effusion Method and Theory—For commercial and ordinary laboratory purposes the effusion method has usually been favored because of the simplicity of the apparatus required and the readiness and speed with which it can be operated and conveniently taken about.

This effusion apparatus, generally known as the Schilling, after one of its original designers, is embodied, with improvements added, in our portable water-contained type, Catalogue No. 111.

The effusion theory on which this apparatus is based is founded upon the fact that the times required for the escape of equal volumes of two gases under the same pressure through the same small orifice are approximately proportional to the square roots of the densities of the gases.

The densities or weights are therefore proportional to the square of the times of effusion.

The specific gravity of a gas is the ratio of the weight of a given volume of the gas to the weight of an equal volume of air, measured at the same temperature and pressure.

Representing the density, or weight, by d and the time of effusion by t, the specific gravity is found as follows:

$$\text{Specific Gravity} = \frac{d\ (\text{gas})}{d\ (\text{air})} = \frac{t^2\ (\text{gas})}{t^2\ (\text{air})}$$

Schilling Apparatus—The Schilling Apparatus (our Cat. No. 111) is the type which has been most generally used in making such tests. This consists of a glass jar about 3½ in. in diameter and about 12 in. deep, in which is inserted a glass tube about 1″ in diameter, graduated each inch from the bottom up. This tube is mounted on a brass plate at the top of the jar, through which it is inserted, and attached to it are a 3-way cock and a small glass tip with platinum orifice plate fused across its upper end.

The test is made by filling the jar with water almost to the top, inserting the graduated tube with the cock open so as to allow the water to enter. The tube is now filled with air by withdrawing it with the tip removed and the cock open. It is re-inserted with the cock closed and the tip replaced. The cock key is then turned to permit the air to escape through the orifice tip, being forced out by pressure of the water rising in the tube from the jar.

As the water reaches the first mark the stop-watch is started and it is stopped as the water reaches the highest mark. The time of effusion is then noted.

The tube is now filled with gas through a rubber tube attached to the side opening of the cock. The cock is then turned to allow the gas to escape through the orifice while timing in the same manner as with the previous test.

The specific gravity of the gas is then calculated from the square of the times of effusion as previously explained.

Bureau of Standards Investigations—Varying results obtained in the use of this apparatus under different conditions and with different gases induced the Bureau to make thorough investigation of the subject in all its phases, as detailed in Technologic Paper No. 94, with the result that a new apparatus was designed, embodying two improvements which reduce inaccuracies to within about 2 per cent., and by the application of correction factors determined by standardization against the specific gravity balance, even closer results are obtained.

The improvements made are, first, in the form of the apparatus and, second, in the orifice tip.

Bureau of Standards Apparatus—By reference to Fig. **29** it will be noted that the jar and graduated tube are replaced by two bulbs mounted on a stand. The bulb at the right (L) is the water reservoir, or leveling bulb, and takes the place of the jar. The one at the left (C) is used as the gas or air container, having an upper and a lower mark on the tubes extending from it above and below.

The upper tube is of very small bore so as to permit of close observation of the meniscus as the water rises to the mark.

The gas container is set in a jar filled with water to protect it from temperature changes. It is held in position at the lower end by being set through a hole in the bottom of the jar. At the upper end it is attached to a 3-way cock of special design, and is held firmly in place by a metal cap over the top of the jar, through which it extends.

The reservoir at the right rests on a bracket from which it can be lifted and replaced in exactly the same position. The reservoir and the gas container are connected by rubber tubing.

The purpose of using these bulbs is to have less difference in the water levels through extending the body of water laterally. This reduces the effusion pressure of the gas and air to a point at which more accurate results can be obtained than with the tube apparatus.

The orifice tip is redesigned to secure greater accuracy by having the orifice of exact diameter shown by experiments to give closest and most uniform results, viz., about .25 mm. The form of the orifice is perfectly round and the edges sharp and free from burr. This is accomplished by working very carefully under the microscope. To permit of making the orifice of such exact size and shape the plate is of hard material, the platinum being alloyed with 15 per cent. iridium, and the thickness reduced to about .04 mm.

The orifice plate is fused between the ends of two pieces of small glass tubing and the tubing is set with cement into a metal socket, one end of which is threaded inside to screw onto the 3-way cock outlet (O) and the other end is protected by a metal cap when not in use.

The complete apparatus is provided with a centigrade thermometer for the water jar, rubber tubing for the gas inlet (I), an extra orifice tip, and a wooden cover with handle to set over the stand and be attached to it for carrying about.

Directions for Operating—The apparatus should be set up and filled with distilled water, with the cock open to the air, by pouring into the reservoir in position on the bracket until the water reaches the mark on the upper tube of the gas chamber just below the cock. Preserve this exact amount of water throughout a series of tests, so the effusion pressure will be constant. The water jar should also be

filled and the thermometer placed in it to the proper depth through the opening in the plate.

The orifice tip, which is kept screwed on the base of the stand when not in use, is now screwed tightly with a wrench on the outlet of the cock (O), care being taken that the washer is gas tight.

Keep the cock turned so the tip will not connect to the gas container when not in use, thus preventing deposit of moisture in the orifice; also have cock turned off gas container when raising reservoir from the bracket, to prevent water being forced into the cock and thence be carried by the gas or air into the orifice.

The apparatus should be tested to make sure that there are no leaks in the gas chamber.

In filling the apparatus with gas or air, care should be taken to insure an uncontaminated sample by rinsing as many times as may be necessary to obtain constant effusion in successive tests. The orifice tube and connections must also be filled with the gas sample.

When using the movable reservoir, care should be taken to replace the reservoir at exactly the same height, so that the effusion pressure will not be changed from one determination to the next.

Any moisture condensed on the edges of the orifice should be removed by passing dry gas through the orifice. The constancy of the air effusion interval is an indication of whether or not an appreciable error is being introduced from this source.

For a specific gravity determination, several consecutive runs should be made on both gas and air. In general, one should secure three or four intervals which agree within 0.5 per cent., or if the interval be more than two minutes, within one-half second, before the average can be considered as satisfactory. It should be noted that an error of 0.5 per cent in timing makes a difference of about 1 per cent. in the

apparent specific gravity. The accuracy of the stop-watch should be checked by comparison with some standard when possible.

In timing, care should be taken to have the eye on a level with the graduation at the time of starting or stopping the stop-watch.

The water in the jar having been allowed to stand until its temperature is the same as that of the room, and precautions taken to prevent any changes of temperature during the test, the gas container is filled with air through the side cock opening (I) by taking the water reservoir off the bracket and lowering it until the water runs out of the container to a point so far below the mark, on the lower tube, that when the reservoir is raised again and placed on its bracket, with the cock closed to the gas container, the water will not rise above the lower mark.

The air should be held confined in this way until it becomes saturated with water vapor and temperatures equalize. This will also permit drainage of water from the interior surface of the gas chamber. This period of rest should be of uniform duration after each filling before making a test.

The cock is now opened to the orifice tip (O) and the air allowed to escape, the time of effusion being noted with the stop-watch, as the meniscus rises from the mark on the lower tube to the mark on the upper tube, just above the gas container. This operation should be repeated three or four times, so as to obtain an average result.

The gas container should now be filled with the gas to be tested by attaching the rubber tube to the side cock opening (I) and lowering the water reservoir as in filling with air. After the usual period of rest the gas should then be passed out through the orifice and timed as with air, several rinsings being made before the usual series of tests to clear the apparatus of air.

Calculation of Results—The above experiments having been made with air and gas saturated with water vapor, let S_s represent the specific gravity of the gas tested under these conditions. Therefore, applying the formula already explained, we have:

$$S_s = \frac{t^2 \text{ (gas)}}{t^2 \text{ (air)}}$$

The specific gravity of a saturated gas, however, compared to saturated air, is different from that of the same gas in dry condition compared to dry air.

Moreover, the specific gravity of a saturated gas will vary at different temperatures and pressures.

The different formulas worked out to make correction of these variations for different temperatures, at the standard barometric pressure of 760 mm., have resulted in the following factors represented by "k":

Temperature	k
0°	
0	0.004
5	.005
10	.008
15	.011
20	.015
25	.020
30	.027

If the specific gravity of a gas in dry condition (S) is known, and it is desired to obtain the specific gravity of the saturated gas referred to, saturated air (S_s) at 25° C., the following formula is applied:

$$S_s = \frac{S + k}{1 + k}$$

For example: Let S = 0.660.

$$\text{Then } S_s = \frac{0.660 + .020}{1.0 + .020} = 0.667$$

If the specific gravity as obtained with an effusion apparatus on saturated gas is to be corrected to that of the dry gas referred to dry air, then the following formula is used:

$$S_s = S_s \ (1+k) - k$$

Giving S_s at 25° C. the value 0.667 as found in the previous example and applying the correction factor k, we have the following result:

$$S = 0.667 \ (1+.020) - .020 = 0.660$$

A further correction may be applied for the particular apparatus in use, if it has been standardized against the specific gravity balance described in Technologic Paper No. 89."

Heating Value and Specific Gravity—When it is impossible to obtain a calorimetric determination of the heating value of a particular gas, the next best procedure is to compute it from the chemical analysis of the gas, using the values shown in the following table for the heating value of the constituent gases.

TABLE No. 17

Kind of Gas	Symbol	Gross Heating Value B. t. u. per Cu. Ft.	Specific Gravity (Air = 1)
Methane	CH_4	1003	0.5529
Ethane	C_2H_6	1754	1.0368
Ethylene	C_2H_4	1578	0.9676
Carbon monoxide	CO	322	0.9671
Hydrogen	H_2	324	0.0692
Hydrogen sulphide	H_2S	668	1.1769
Nitrogen	N_2	....	0.9701
Carbon dioxide	CO_2	....	1.5195
Helium	He	....	0.1382
Oxygen	O_2	....	1.1052

Multiply the percentage of each gas present by its corresponding heating value per cubic foot, and add the products.

The specific gravity is obtained in the same manner from the specific gravities and proportions of the constituent gases shown by the analysis.

Such computed results are necessarily subject to whatever errors there may be in the analysis of the gas, and unless this has been done with great care and precision, a wide discrepancy may exist between the calculated and the actual values. The preceding B. t. u. values are gross or high values, and are based on one cubic foot of gas at 60 deg. fahr. and four ounce pressure, or 14.65 pounds per square inch absolute.

Illuminating Properties of Natural Gas—Natural gas in connection with the mantle of alkaline earth (cerium and thorium) has produced the cheapest and best illuminant. When natural gas could be had at twenty-five cents per thousand cubic feet and fifty candle power can be obtained from the consumption of two and one-half cubic feet per hour with a mantle, the cost of one candle power per hour was but 0.00125 of a cent.

In an ordinary argand burner with chimney, natural gas will give about twelve candle power with a consumption of five to six cubic feet per hour. If consumed in an ordinary tip, seven to eight cubic feet per hour will yield six candle power.

All natural gas has not the same illuminating value. In some districts it carries a small percentage of heavier hydrocarbons, which add much to its illuminating properties.

TESTS TO DETERMINE POISONOUS GASES IN NATURAL GAS FROM THE CADDO (LA.) FIELD

In presenting the following tests by Prof. E. S. Merriam, it must be borne in mind that the results obtained do not establish the fact that all natural gas is harmless. The gas used in the tests was practically pure methane with no detectable quantities of higher hydrocarbons.

TESTS CONDUCTED ON THE NATURAL GAS SUPPLY OF LITTLE ROCK, ARKANSAS.

By E. S. MERRIAM, PH. D.

"The tests described below were made with the object of ascertaining whether the natural gas supplied to its consumers, by the Little Rock Gas and Fuel Company, contained any poisonous constituents.

There is a widespread belief that many varieties of natural gas contain carbon monoxide. Work done in the Bureau of Mines makes it probable that carbon monoxide is never found in natural gas. Its reported presence in many analyses is due to the use of unsuitable methods of examination.

Two tests for carbon monoxide were made: 1st, when blood is exposed to an atmosphere containing carbon monoxide the gas is absorbed and a compound of carbon monoxide with the hemoglobin of the blood is formed, having a pink or purplish color quite different from the color due to oxyhemoglobin. The formation of this color is one of the most positive and conclusive tests we have for carbon monoxide.

A dilute solution of steer's blood in water was prepared (about 1 in 300). Three Nessler tubes were filled with this solution. On passing one liter of the city gas supply through the blood solution, in one of the tubes, no change in color was noted. In order to show that carbon monoxide, if present in the gas, could be detected by this test, a mixture of city gas and carbon monoxide was prepared—10 cc. of carbon monoxide was mixed with two liters of city gas, making a 0.5 per cent. mixture. This mixture was bubbled through a Nessler tube containing blood; the color appeared after the passage of about a quarter of the quantity of the mixture.

The blood tube which had been previously treated with the city gas alone and had failed to give the reaction, gave it very readily when treated with the mixture of carbon monoxide and gas.

2nd: A dilute solution of palladium nitrate is reduced by carbon monoxide and also by hydrocarbons of the ethylene series, by hydrogen sulphide, and by free hydrogen. The metal appears in the form of very fine black particles floating about in the light yellow liquid. A thin smoky deposit of metal is also formed on the glass of the test tube near the surface of the liquid. These fine particles of palladium coalesce in a short time and appear in the bottom of the test tube as a black sediment.

On passing one liter of the city gas through 5 cc. of a solution of palladium nitrate, no change whatever could be noticed, even on comparing the solution with a blank of 5 cc. of the original solution. The above described mixture of carbon monoxide and gas gave the reaction unmistakably.

The failure to get a positive result from the city gas with this solution not only excludes carbon monoxide, but also eliminates free hydrogen, hydrocarbons of the ethylene series, and hydrogen sulphide.

A special test for hydrogen sulphide was further made by passing two liters of city gas through a U tube containing granular lead acetate. No sign of blackening could be detected. This is an extremely delicate test and minute traces would have made themselves evident.

Absorption experiments using bromine water and ammoniacal cuprous chloride in the ordinary Hempel form of apparatus failed to show any carbon monoxide or ethylene hydrocarbons. This method was employed because these are the customary reagents used in technical gas analysis, although the tests by blood and palladium salts are far more decisive.

As a further test of a different sort, a canary bird was placed in a pasteboard box of the following dimensions:—17 x 23 x 24 inches; the capacity of the box was therefore 154 litres. Holes were bored for the admission of gas and provision was made for obtaining a sample of the atmosphere within the box. A glass plate which could be pasted on was provided so that the bird could be observed. After placing the bird within the cage and closing the glass door, forty litres of gas were introduced into the box. This would give an atmosphere within the box containing at the start about 35 per cent. of gas. The glass door was then pasted down air-tight, and the box was left undisturbed for one hour and six minutes. During this period the bird showed no signs of distress and was apparently as well as ever at the close of the test. At the end of the test a sample of the atmosphere within the box was obtained and showed the following result on analysis:—92.05 cc. were taken and after treatment with KOH lost 0.2 cc. This represents 1.22 per cent of carbon dioxide mostly formed by the bird's breathing. After removal of oxygen by alkaline pyrogallic acid there remained 74.15 cc. From these figures the percentage of air in the box is calculated to be 93.1, or the atmosphere of the box contained 6.9 per cent. of gas. A confirmatory and more accurate result obtained by combustion showed 7.35 per cent. of gas.

In order to determine the nature and amount of the combustible constituents of the gas it was burned in a form of apparatus devised by the Bureau of Mines. The gas was handled over mercury and burned with pure oxygen, by the use of a hot spiral of platinum wire. The percentage of carbon dioxide originally present in the gas, was previously determined and its presence allowed for in the calculations. The volume of carbon dioxide and the contraction, due to burning, were corrected for deviation from the true gas laws. The measuring burette had been previously calibrated and

was provided with a compensating device to avoid errors due to changing temperature and pressure.

Below are the results of combustions:—

Oxygen Taken	Gas taken	Volume after Burning	Volume after KOH	Corrected volume of CO_2	Corrected value of Contraction	Empirical formula of hydrocarbons present
97.35	42.85	55.8	13.4	41.95	84.3	$CH_{4.03}$

The gas is therefore almost wholly methane with a small amount of nitrogen and carbon dioxide. The gas can act physiologically only by diluting the atmospheric oxygen present.

Summarizing the above results we have:—

Percentage of Methane	97.8
Percentage of Carbon Dioxide	1.25
Percentage of Nitrogen	0.95
Percentage of Carbon Monoxide	0.00
Percentage of Olefines	0.00
Percentage of Hydrogen	0.00
Percentage of Hydrogen Sulphide	0.00
	100.00

PHYSIOLOGICAL TEST OF THE NATURAL GAS FROM CADDO (LA.) FIELD.

By E. S. MERRIAM, PH. D.

"A chemical analysis, performed August 7th, having shown the natural gas supply of Little Rock to consist almost wholly of methane, it was believed that a physiological test would furnish further and conclusive evidence that the gas does not possess toxic qualities.

Mr. B. J. Gifford consented to the use of the kitchen of his house at 2605 State Street for the test. This room measured 16 feet in length, 12 feet in width and 11 feet in height; its total capacity, therefore, was 2,112 cubic feet. The gas pipes were disconnected at the stove and hot water heater, in order to allow a free flow of gas into the room. Mr. W. F. Booth, Mr. B. J. Gifford and Prof. E. S. Merriam remained in the room during the entire period of the test. Dr. J. H. Kinsworthy was admitted when the test had been under way for 31 minutes and he remained until the end.

A meter in the basement of the house allowed the total quantity of gas admitted to the room to be measured. The windows and doors of the room were tightened somewhat by stopping the cracks with newspaper. Prof. Merriam determined the percentage of oxygen in the air of the room at the beginning of the test, and at frequent intervals during the test; so that a close record of the amount of gas in the atmosphere of the room could be obtained at any moment.

The test was begun at 2:55 P.M., Mr. Booth, Mr. Gifford and Mr. Merriam being then in the room. The initial reading of the gas meter was 6300. At 3:31, the gas supply was turned off and the final reading of the meter was 6750, showing that 450 cubic feet of gas had entered the room during this interval of 36 minutes. The gas, therefore, came in at the rate of 12.5 cubic feet per minute. At 3:26, Dr. Kinsworthy was admitted to the room, 5 minutes before the

gas supply was shut off. At 3:38 a bottle was filled with water, the water poured out and the bottle tightly corked. In this way a sample of the atmosphere of the room at that moment, was secured. It was tested later. At 3:54 P.M., or 59 minutes after the start of the test, a second sample of the atmosphere of the room was obtained. At 4:00 P.M., the test was brought to a close by opening the doors and windows.

In spite of the fact that the day was uncomfortably warm, none of the persons undergoing the test felt the slightest discomfort; there was no headache, nausea, dizziness, nor any of the usual symptoms of gas poisoning, experienced by any of the four men, either during or after the test.

Below are recorded the observations made during the test:

Time P. M.	Percent. of Oxygen	Percent. of Air	Percent. of Gas	Remarks
2.55	20.6	100.0	0.0	Start of test.
3.00	20.1	97.6	2.4	....
3.05	19.6	95.2	4.8	....
3.15	18.7	90.8	9.2	....
3.26	17.9	86.9	13.1	Dr. Kingsworthy entered.
3.31	....	....	....	Gas turned off.
3.35	18.4	89.3	10.7	....
3.38	....	....	....	First sample of atmosphere taken.
3.41	18.8	91.25	8.75	....
3.49	19.0	92.25	7.75	....
3.54	19.05	94.6	5.4	Second sample of atmosphere taken.
4.00	....	....	....	End of test.

The sample of atmosphere obtained at 3:38 was tested by withdrawing the cork and applying a match. The gas ignited and burned quietly, flaring back into the bottle. The sample collected at the end of the test was tested in the same way, but did not burn or explode. This result was expected, as the Bureau of Mines has found that a mixture of air and

methane must contain 5.5 per cent. of methane to be explosive. The sample collected at 3:54 contained, according to the analysis, only 5.4 per cent. of natural gas, or methane, and could not, therefore, be expected to explode.

From the analytical results it is evident that from about 3:10 to 3:50 there was gas enough in the atmosphere of the room to form an explosive mixture.

Two other important points are to be noted from the analytical figures.

First, the rate of escape of gas from the room after the supply was shut off is quite rapid, the percentage of gas falling from 13.1 to 5.4 in 28 minutes. This was in a room where all the doors and windows were closed and the cracks stopped up. In an ordinary room it seems extremely unlikely that sufficient gas could accumulate to reduce the oxygen percentage to a dangerous degree.

Second, the gas was introduced into the room at the rate of 12.5 cubic feet per minute; the room was of an average size, but the percentage of oxygen was reduced to only 17.9; even with all the burners of a stove turned on full and all gas jets open, gas could not be introduced at a higher rate than two cubic feet per minute.

This test shows, therefore, that no ill effects whatever can be attributed to an atmosphere containing unburned Little Rock Natural Gas. Four men observed no effect whatever from breathing an atmosphere containing far more gas than is ever likely to result from accidental causes."

PHYSIOLOGICAL EFFECTS OF NATURAL GAS.*

Effects of Natural Gas on Canaries—The artificial illuminating gas of cities, made by the destructive distillation of coal and oil or by the action of steam on hot coke, contains from 8 or 10 per cent upward of carbon monoxide. In some cities the gas may contain as much as 30 per cent of carbon monoxide, and many deaths have been caused from

*From Technical Paper No. 107, by G. A. Burrell and G. G. Oberfell.

its escaping and the user breathing it. On the other hand, natural gas contains no carbon monoxide or other poisonous gases, excepting in rare instances hydrogen sulphide. But, to the authors' knowledge, no natural gas containing hydrogen sulphide is used in any city. There are present in the natural gas used in many cities small proportions of the higher paraffin hydrocarbons, butane and pentane, and these, if inhaled in sufficient quantity, exert an anesthetic action on the human system. It is generally known, for instance, that ordinary gasoline, which contains large quantities of pentane and hexane, will give many people a headache if inhaled in sufficient quantity and often has produced a condition similar to alcoholic intoxication. Methane, the chief constituent of natural gas, is physiologically inert. Perhaps the same can be said of ethane, but most likely propane has some effect and butane and pentane undoubtedly have. In most natural gas the proportions of butane and pentane are probably too small to have any decidedly dangerous effect on man.

In order to get some information on this matter some experiments were made on canaries. Various proportions of the natural gas used in Pittsburgh were introduced with pure air in a 10-liter bell jar and the effects noted. The results were as follows

Effect on Canaries of Breathing Mixtures of Natural Gas and Air.

Test No.	Natural gas	Air		Carbon dioxide	Effect on Canary
		Oxygen	Nitrogen		
	Per cent.	Per cent.	Per cent.	Per cent.	
1	76.9	4.8	18.2	0.1	Immediate collapse.
2	69.9	6.1	23.1	.9	Do.
3	66.3	6.9	26.1	.7	Showed immediate distress, but did not collapse in 1 hour's time.
4	65.8	7.1	26.9	.2	Immediate collapse.
5	63.0	7.5	28.4	1.1	Showed immediate distress, but did not collapse in 1 hour's time.
6	49.3	10.6	40.0	.1	Showed unsteadiness of movement for the first 5 minutes and was more or less drowsy during the exposure which lasted 1 hour.
7	44.5	11.6	43.8	.1	Do.
8	34.5	13.7	51.7	.1	Only symptom in 1 hour's time was drowsiness and unsteady movement.

According to the foregoing table, the proportion of natural gas in air required to produce collapse in canaries is very large (65 per cent or more). With as much as 63 per cent collapse did not occur in one hour's time, although the distress was immediate. Distress was evinced by the canaries opening their bills and breathing rapidly and finally squatting on the perch in a lethargic manner. Some of the canaries were more resistant than others.

COMPARISON WITH EFFECTS OF ATMOSPHERES DEFICIENT IN OXYGEN.

Effect on Canaries of Atmospheres Low in Oxygen—The results of these experiments indicate that as far as the action of natural gas on canaries is concerned it is largely a question of a deficiency of oxygen produced by diluting the air with natural gas. In investigations to determine the suitability of using small animals in mines to detect atmospheres dangerously low in oxygen, the results of which are described in Technical Paper 122*, experiments were made to determine the resistance of canaries to low-oxygen atmospheres produced by diluting air with nitrogen. The results obtained, as may be seen from the table following, show that the effect on the canaries is much the same as that of natural gas.

In conducting the experiments, atmospheres containing various percentages of nitrogen and oxygen were prepared in bell jars of 10 liters capacity. The nitrogen used analyzed 97.8 per cent nitrogen and 2.2 per cent oxygen. Three canaries, designated in the table as A, B, and C, were used in the experiments.

* Burrell, G. A., and Oberfell, G. G., Relative effects of atmospheres deficient in oxygen on small animals and on men: Technical Paper 122, 1915.

Effect on Canaries of Breathing Atmospheres Low in Oxygen.

Test No.	Canary used	Composition of atmosphere					
		At beginning of experiment			At end of experiment		
		Oxygen	Nitrogen	Carbon dioxide	Oxygen	Nitrogen	Carbon dioxide
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	B.........	9.42	90.48	0.10	8.50	90.90	0.60
2	C.........	9.25	90.65	.10	....	....	....
3	A.........	7.65	92.25	.10	7.55	92.05	.40
4	C.........	7.83	92.07	.10	....	....	....
5	A and C...	7.10	92.80	.10	....	....	....

REMARKS

TEST 1—The canary, B, showed immediate distress as evinced by rapid breathing, open bill, and unsteadiness. In 10 minutes' time the bird was apparently in normal condition, with the exception of slight increase in the rate of breathing. It was removed from the atmosphere at the end of one hour's time.

TEST 2—The behavior of the canary, C, was similar to that of the bird in the previous experiment.

TEST 3—The canary, A, showed immediate distress by panting and unsteadiness, but did not collapse or evince any more distress than the bird in Test No. 1. It was left in the atmosphere for one hour.

TEST 4—The canary, C, collapsed as soon as it was placed in the atmosphere. It breathed very slowly with eyes and bill closed, but recovered its normal state in less than a minute after it was removed to fresh air.

TEST 5—One canary, A, showed distress but did not collapse in 20 minutes' time. Another canary, C, was placed in the atmosphere and immediately collapsed.

The canaries showed some distress in atmospheres containing 9.4 per cent of oxygen and more pronounced distress in atmospheres containing as low as 7.6 or 7.8 per cent; but in an atmosphere containing as little as 7.1 per cent of oxygen they may or may not collapse.

Effect on Men of Atmosphere Low in Oxygen—In a test to determine the effects on man of atmospheres low in oxygen described in Technical Paper 122, a member of the Bureau of Mines breathed air in and out of a bag having a capacity of about 70.0 liters, the exhaled carbon dioxide being removed by means of a can of caustic potash inserted between his mouth and the bag, and was rendered unconscious when the oxygen content of the air had fallen to about 7.0 per cent. The effect of action of "oxygen want" is instructive. The subject felt warning symptoms previous to collapse, but did not believe himself in any danger of losing consciousness, and, in fact, wanted to continue the experiment. He felt no real distress until some time after the experiment, but on the next day was decidedly unwell.

In its insidious action "oxygen want" acts as carbon monoxide frequently does, that is, when the oxygen is slowly decreased. One difficulty in comparing the mode of action of the two lies in the scarcity of experimental data on the effects on men of atmospheres low in oxygen.

Some light is thrown on the action of low-oxygen atmospheres by an accident that occurred in the Lodge Mill colliery, Huddersfield, England,* in which three men were overcome by black damp in an unused part of the mine. Two men, A and B, were overcome by the black damp at 3.30 A. M. A third man, C, was overcome at 4 A. M. in an attempt to rescue his comrades. At 1 P. M. of the same day rescuers equipped with breathing apparatus removed C, and about an hour later removed A. A little later B was found dead. Both A and C were in a critical condition, but still breathing. A died three days later. The air in which the men were overcome was high in methane and corre-

* See Lloyd, W. D., The use of rescue apparatus at Lodge Mill colliery, Huddersfield, with a note by J. S. Haldane: Coll. Guard., Nov. 7, 1913, vol. 106, pp. 957-958.

spondingly low in oxygen. Haldane† comments on this disaster as follows:

All the facts recorded indicate that the men were overcome by the insufficiency in the oxygen percentage of the air. There was no reason to suspect the presence of carbon monoxide as there was no gob fire or heating. In addition, the blood of the dead man was black, not red, as it would have been if death was due to carbon monoxide. It is probable that sufficient fire damp was present to reduce the oxygen to 7 or 8 per cent. The fact that A did not recover was due to exactly the same cause which often prevents men recovering after severe carbon-monoxide poisoning. The tissues have been severely damaged by the prolonged exposure to dearth of oxygen, so that although the oxygen supply is completely restored, recovery is doubtful. In the case of A the post-mortem examination revealed the fact that the heart was dilated. Probably the heart muscles and the other tissues were in a condition of fatty degeneration caused by the want of oxygen. The writer has seen other similar cases of dilation simulating severe heart disease, and only slowly recovering, after prolonged exposure to carbon-monoxide poisoning. So far as he is aware, however, this is the only recorded case of death after partial recovery from exposure to an atmosphere which was simply deficient in oxygen, apart from the presence of carbon monoxide.

In regard to the oxygen deficiency required to cause distress in men, Haldane* says:

When the oxygen content of the air is gradually reduced by the absorption of the oxygen or (what is exactly the same thing) by addition of nitrogen, very little may be felt before the occurrence of impairment of the senses and loss of power over the limbs. If the reduction is gradual and the symptoms be carefully watched, it will be noticed that at about 12 per cent. oxygen—that is with a reduction of 9 per cent.—the respirations become just perceptibly deeper. At 10 per cent. the respirations are distinctly deeper and more frequent, and the lips become slightly bluish. At 8 per cent. the face begins to assume a leaden color, though the distress is still not great. With 5 or 6 per cent. there is marked panting, and this is accompanied by clouding of the senses and loss of power over the limbs, which would probably end sooner or later in death. It is probable that any sudden exertion made in air markedly deficient

* Haldane, J. S., The causes of deaths in colliery explosions and underground fires: Report to the Secretary of State for the Home Dept., 1896, p. 15.

†Haldane, J. S., Note on paper by W. D. Lloyd: Coll. Guard., vol. 106, 1913, p. 958.

in oxygen may lead to temporary loss of consciousness, so that sudden efforts should be avoided in all cases where, through accident or necessity, a man is in an atmosphere which will not support light and in such a position that he might fall into worse air or otherwise injure himself. When air containing less than 1 or 2 per cent. of oxygen is breathed, loss of consciousness, without any distinct warning symptoms, occurs within 40 or 50 seconds. Loss of consciousness in air deprived of oxygen is more rapid than in drowning or strangling, since in the former case not only is the supply of fresh oxygen cut off but the oxygen previously in the lungs is rapidly washed out, loss of consciousness is quickly followed by convulsions, which are followed by cessation of the respiration. The heart still continues to beat, in the case of cats and dogs, for from two to eight minutes; in men this period is probably much longer, for it seems to be the general rule that the larger the animal the longer it resists asphyxiation. So long as the heart is beating, however feebly, animation may be restored by artificial respiration. This may require to be continued for a considerable period, as the after effects of deprivation of oxygen are very serious and the respiratory center may not recover for some time.

The experiments cited show that oxygen deprivation begins to affect men in about the same time it does canaries, and the percentages that cause collapse are not much different. Atmospheres that will cause animals to collapse vary to a certain extent, and presumably the same is true of men.

Effect of Natural Gas on Man—As far as the diluting action of nitrogen and natural gas in lowering the oxygen content of air is concerned, the two are nearly similar in the effects produced on canaries. Possibly the same is true as regards man, but to make certain of this point experiments would have to be made on human subjects. One is safe, however, in drawing the conclusion that a large proportion of natural gas in mixture with air is required to affect man and that the danger of death to the occupants of a room because of natural gas escaping from an open gas jet is remote, because of the very large quantity of gas required. An ordinary natural-gas burner in a house, used for giving light, burns about 4 cubic feet per hour. At this rate, to

reduce the proportion of oxygen in the air of a room 9 feet high and 15 feet square to 10 per cent, the burner would have to flow gas for about 263 hours, assuming that no gas leaked out of the room through the door jambs, window jambs, and cracks in the walls (an impossibly tight condition, by the way). Therefore the possibility of suffocation being produced by natural gas under such conditions is very remote. Of course, in a small room where several burners were flowing the danger would be greater. The danger of explosion from the accidental lighting of a mixture of natural gas and air is much greater than that of suffocation from it. The proportion of natural gas in air required to make the mixture explosive is about 5 to 12 per cent, whereas to produce suffocation apparently requires about 60 per cent.

Artificial illuminating gas made from coal, on the other hand, may be poisonous when as little as 1 per cent (based on only 10 per cent of carbon monoxide in the gas) of it is in the room, and dangerously so when 2 per cent is present. It is also explosive in relatively small proportion, the low limit being about 7 or 9 per cent and the high limit 18 to 21 per cent.

Natural Gas—Natural gas is a combustible gas that comes from the earth. No doubt it received its name for two reasons, viz., one on account of it coming naturally from the earth and the other to distinguish it from artificial or manufactured gas.

Both natural and artificial gas are used for practically the same purposes, viz., heating, lighting and power.

It would not have been misnamed to have called it methane or marsh gas, as it is mainly composed of it.

In the broad sense of the word one might call carbonic acid, nitrogen, casinghead or sulphuretted hydrogen, natural gas, as they all come from wells in the same manner, *i. e.*, in a natural state.

TABLE No. 18—RESULTS OF EXAMINATION OF

Date of Sampling	Laboratory No.	State	County	Town
1914				
November 9...	5605	Arkansas and Texas	Miller and Bowie	Texarkana....
May 8........	5275	Indiana..........	Hamilton.....	Noblesville...
September 8...	5413	Kansas..........	Allen........	Iola.........
September.....	5351	"	Shawnee.....	Topeka.......
October.......	5405	"	Leavenworth..	Leavenworth..
August........	5590	Kentucky........	Jefferson.....	Louisville.....
November 21..	5344	Louisiana........	Caddo.......	Lewis........
"	5643	"	De Soto......	Mansfield.....
November 6...	5588	Missouri........	Jasper.......	Joplin........
July 7.........	5271	New York........	Allegany.....	Alma........
April..........	5277	"	Erie.........	Buffalo.......
March........	5269	Ohio............	Hamilton.....	Cincinnati....
July..........	5101	"	Cuyahoga....	Cleveland....
"	5198	"	Washington...	Marietta.....
July 10........	5273	"	Clark........	Springfield....
February......	4082	"	Franklin.....	Columbus†...
August 27.....	5403	Oklahoma........	Washington...	Bartlesville...
August........	5373	"	Rogers.......	Chelsea......
August 8......	5401	"	Logan........	Guthrie......
October.......	5393	"	Muskogee....	Muskogee....
September.....	5307	"	Nowata......	Nowata......
"	5415	"	Osage........	Pawhuska....
September 6...	5418	"	"	" ....
August........	5387	"	"	" ....
"	5324	Pennsylvania.....	Clarion.......	Oil City......
"	5312	Texas............	Navarre......	Corsicanna....
October.......	5445	"	Dallas.......	Dallas.......
"	5443	"	"	" ....
"	5345	"	Tarrant......	Fort Worth...
September.....	5375	"	"	" ....
August........	5477	"	"	" ....
"	5479	"	"	" ....

† Samples collected at Lord Hall, Ohio State University.

SAMPLES OF NATURAL GAS FROM 25 CITIES.*

C_nH_{2n+2}	CH_4	C_2H_6	CO_2	N_2	O_2	B. t. u. per cubic foot (760 mm. Pressure)		Specific Gravity	
						0° C.	60° F.	Calculated	Determined
Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.				
96.0	96.0	0.0	0.8	3.2	0.0	1,022	967	0.58	....
93.0	86.8	6.2	0.8	6.2	0.0	1,040	984	0.62	....
97.7	96.4	1.3	0.9	1.4	0.0	1,051	994	0.58	0.58
95.5	88.8	6.7	0.8	3.7	0.0	1,070	1,013	0.61	....
95.8	91.3	4.5	0.8	3.4	0.0	1,066	999	0.60	....
98.2	77.8	20.4	0.0	1.8	0.0	1,205	1,143	0.66	....
96.5	96.5	0.0	1.4	2.1	0.0	1,028	972	0.58	....
97.3	97.3	0.0	0.4	2.3	0.0	1,066	1,009	0.59	....
96.9	92.6	4.3	0.6	2.5	0.0	1,066	1,009	0.59	....
99.9	68.8	31.1	0.0	0.1	0.0	1,312	1,241	0.71	....
95.1	79.9	15.2	0.0	4.9	0.0	1,134	1,073	0.65	....
99.3	79.8	19.5	0.0	0.7	0.0	1,213	1,147	0.65	....
98.7	80.5	18.2	0.0	1.3	0.0	1,196	1,131	0.65	....
98.8	73.2	25.6	0.0	1.2	0.0	1,256	1,188	0.69	....
95.0	80.3	14.7	0.0	5.0	0.0	1,129	1,068	0.65	....
98.5	80.4	18.1	0.0	1.5	0.0	1,193	1,129	0.65	....
95.5	92.4	3.1	1.4	3.1	0.0	1,042	986	0.60	....
93.1	75.4	17.7	0.3	6.6	0.0	1,132	1,071	0.67	....
90.0	69.4	20.6	0.1	9.9	0.0	1,122	1,062	0.70	....
96.2	92.1	4.1	0.4	3.4	0.0	1,057	1,000	0.59	....
95.2	95.2	0.0	1.3	3.5	0.0	1,014	960	0.58	....
94.2	88.6	5.6	1.4	4.4	0.0	1,048	991	0.61	0.64
87.2	66.5	20.7	0.3	12.5	0.0	1,093	1,034	0.71	0.72
93.9	85.1	8.8	1.0	5.1	0.0	1,070	1,012	0.63	0.65
98.9	67.6	31.3	0.0	1.1	0.0	1,302	1,232	0.71	....
98.0	98.0	0.0	0.7	1.3	0.0	1,044	987	0.57	....
61.5	50.6	10.9	0.1	38.4	0.0	742	702	0.77	0.76
61.7	51.3	10.4	0.1	38.2	0.0	740	700	0.76	0.76
61.7	51.5	10.2	0.0	38.3	0.0	738	698	0.76	....
61.1	51.1	10.0	0.0	38.9	0.0	730	691	0.76	....
61.5	50.6	10.9	0.1	38.4	0.0	742	702	0.77	....
61.3	50.6	10.7	0.1	38.6	0.0	738	698	0.77	0.77

* From Technical Paper No. 109, by G. A. Burrell and G. G. Oberfell.

Methane, the main constituent of natural gas, is the lightest known hydrocarbon, having a specific gravity of .553 and at normal temperatures would never exist as a liquid. The boiling point of methane is —265. deg. fahr. The natural gas man knows it as a gas only.

Often natural gas carries heavier hydrocarbons, some of which could be properly termed gasoline vapor as they could exist as a liquid at normal temperatures. They exist as part of the gas however, and are just as much an integral part of the whole gas mixtures as the methane itself. One can separate the methane by essentially the same steps as gasoline can be separated, namely, by compressors and refrigerators

Prior to 1910 very little was known about taking gasoline from natural gas or casinghead gas and when contracts were drawn between the buyer and the seller the words "natural gas" were used. No thought was given to the possible gasoline content in the future as it was practically unknown. In fact very little if any natural gas carried any gasoline in the early days as practically all fields were new and the pressure of the gas was high.

The words "natural gas" were first used by the drillers who were drilling for oil and had drilled into a vein of natural gas. No doubt the first words that came into their mind were natural gas. No change in the name has ever been suggested.

Many contracts were written covering the sale of natural gas which at the time of writing the contracts carried no hydrocarbons other than methane with a possible trace of ethane. Since that time the gas fields supplying the gas became older, the pressure declined and the natural gas became heavier due to its picking up heavier hydrocarbons. This change was very gradual but certain whenever the field was located near an oil field or the gas from any field came in contact with an oil bearing strata. The lower the

rock pressure of the field the greater the percentage of gasoline vapor in the gas.

No mention was made, in the early contracts for the sale of natural gas, of the possible gasoline content of it. To-day, these contracts are causing more or less trouble due to this fact, as the majority of the gas fraternity now fully appreciate the value of the gasoline content in lean natural gas and casinghead gas.

When a gas field is near an oil field or an oil-bearing strata and the gas pressure decreases, the gas becomes heavier due to the gas "picking up" more hydrocarbons. Whenever this occurred the percentage of methane would decrease as the percentage of the heavier hydrocarbons increased. With this change in the analysis the specific gravity of the gas increased.

The specific gravity of methane is .553 which, outside of helium, is the lightest constituent of natural gas. The gravities of other hydrocarbons are as follows:—

TABLE No. 19

	Specific Gravity	Lb. per M. cu. ft. of Gas
Methane	.553	45.20
Ethane	1.037	83.95
Propane	1.520	122.69
Butane	2.004	162.25
Pentane	2.488	201.00
Hexane	2.972	240.55

Pentane and hexane, whose boiling points are 97 and 156 deg. fahr. respectively, could be called gasoline vapor.

Butane, which will boil at 34 deg. fahr., could also be considered gasoline in itself if the temperature were below its boiling point. While butane will boil at 34 deg., which can be called a winter temperature, it will be found in any high gravity gasoline in small quantities, even though the temperature of the atmosphere is much higher than 34 deg. fahr.,

hence butane, pentane and hexane and still heavier hydrocarbons, could justly be called gasoline vapors.

In the "Hand Book of Casinghead Gas", 2nd Edition, pages 32 to 48, the subject of the origin of casinghead gas is very carefully covered and after reading it there can be very little doubt in one's mind regarding the ability of natural gas to "pick up hydrocarbons" whenever it comes in contact with an "oil-bearing strata' when the pressure and temperature conditions are right.

When a natural gas field is first drilled in, the rock pressure is usually high, generally dependent upon the depth of the wells, and as the field gradually becomes depleted the rock pressure drops until eventually it may be necessary to install a compression plant and take the gas at a vacuum from the wells.

The boiling points given in the table opposite p. 110 are for atmospheric pressure and when under pressure the boiling points raise as the pressure raises. This is also true of steam as shown in the following table:

TABLE No. 20

Pressure of Water in lb.	Boiling point deg. fahr. at 14.7 atmos. press.
0	212
50	297.7
100	337.9
150	365.9
200	387.9
250	406.1

With the foregoing explanation it is plain how natural gas, even though it may have passed through an oil strata, does not pick up any heavy hydrocarbons when the pressure is high The boiling points of the gasoline lying in the oil are too high, due to the high pressure, to permit vaporization.

TESTIMONY AND DECISION IN A LAW-SUIT INVOLVING THE MEANING OF THE TERM "NATURAL GAS."

On the following pages are printed portions of the testimony given in a law-suit in which the gas purchaser obtained an injunction to prevent the field company from taking the gasoline from the gas. Decision was finally rendered, making the injunction permanent.

The testimony mentioned is not given as necessarily expressing the practical gas man's idea of the meaning of the words "natural gas" but because it contains much material of general interest as well as that bearing directly upon the subject.

The testimony selected is from two witnesses only: one for the defendant and one for the plaintiff. A summary of the judge's decision follows the testimony.

The testimony of each witness given brought out the general line of defence, or attack of either side. Other witnesses appearing testified along the same general lines for his side. Only portions of the testimony considered of special interest to the case are given.

T. R. WEYMOUTH.

Q. Will you explain fully the difference between a chemical compound and a mixture?

A. A chemical compound has the atoms drawn together or attracted to each other by chemical affinity. A mechanical mixture is simply a state in which the different compounds are closely intermingled but there is no chemical attraction between them.

Q. Will you describe, Mr. Weymouth, the three states of matter?

A. Matter exists in a solid, liquid, or the gaseous state.

Q. Are these fixed conditions or variable?

A. They are variable, depending upon the conditions of the surrounding media, or the temperature and pressure, so to speak.

Q. State whether or not various substances are susceptible of existing in these different conditions.

A. Yes, they are. Of course all substances can exist in the three states mentioned.

Q. In what way can a change from a liquid to the gaseous condition, and in the same manner from a solid to the liquid condition, be brought about?

A. By the application of heat to the body just as one applies heat to water to convert it from the liquid to the gaseous state or to convert it from a solid to the liquid state, pressure variations will effect the same change.

Q. Then whether a substance is liquid or gas will depend upon the conditions surrounding it? A. Decidedly.

Q. In what condition of substances can they mix together, as you have stated these different compounds exist in natural gas—can that condition of diffusion exist in liquids as well as gases?

A. Yes, precisely the same.

Q. Do you know about the composition of crude oil?

A. Yes.

Q. Explain what sort of a substance that is.

A. That is likewise a mixture of hydrocarbons which are very much more complex in their nature than natural gas, but it also contains other substances.

Q. A liquid, like natural gas, is not a compound?

A. It is a multiplicity of natural compounds.

Q. What is diffusion?

A. That is the passing of the molecules of one substance into and among the molecules of a neighboring substance.

Q. Is that the condition which exists when those compounds are mixed either in a liquid or gaseous form?

A. Yes.

Q. What do they do in gas?

A. In gas the molecules are flying about at a high velocity in all directions and maintain a straight path until

they come in contact with the walls of the containing vessel, or with other molecules that may be present. The molecules of one gas find their way into the space occupied by the molecules of the other gas, and they gradually intermingle until eventually the two are thoroughly mixed.

Q. But they do this without uniting chemically into one compound? A. Yes.

Q. In crude oil do you have any of these same hydrocarbon compounds that you have mentioned as existing in natural gas?

A. Yes, some of the hydrocarbons of crude oil are exactly the same as those mentioned in natural gas.

Q. And if the crude oil is heated what will be the effect as to these lighter hydrocarbons?

A. They reach a temperature which vaporizes them at the pressure existing within the mass, and they pass off as a gas.

Q. State whether or not gasoline, as the term is generally understood, is a single chemical compound, or a mixture such as you have described a natural gas and oil to be.

A. Gasoline is a mixture of various compounds.

Q. Are those compounds always the same in every gasoline?

A. No, the constitution of gasoline is just as erratic as the constitution of natural gas.

Q. What hydrocarbons usually enter into the composition of gasoline?

A. The bulk of the gasoline body is usually made up of the hydrocarbons pentane, hexane and heptane, with smaller and smaller proportions of the hydrocarbons going either up or down in the series.

Q. Now, if the gasoline is very light, practically a gas, what will be the composition?

A. That indicates a preponderance of butane or possibly pentane, or both, in the gasoline, the lighter hydro-carbons.

Q. And if it is heavier?

A. Then the heavier hydrocarbons predominate, such as heptane or octane.

Q. Is there any fixed combustion which is said to be gasoline? A. No.

Q. Is there any fixed mixture or combination that is said to be natural gas?

A. No, sir.

Q. Is there any fixed combination that is said to be crude oil? A. No, sir.

Q. They will vary?

A. Yes, they will vary. They are very loose terms.

Q. State whether or not these hydrocarbons which you mention as being in gasoline are also to be found in all ordinary crude oils, and natural gases.

A. Yes, in the great bulk of them.

Q. Now, Mr. Weymouth, as these substances, butane, pentane and hexane, which are the principal ingredients of gasoline as they exist in the natural gas as it comes from the wells, state what is their condition or state as to being a gas or liquid.

A. They exist in a gas as a gas.

Q. What do you mean, Mr. Weymouth, by the boiling point?

A. The boiling point of a liquid at a given pressure is that temperature at which the state of the substance of the liquid changes from a liquid to a vapor or gas.

Q. Then you need to know two things: the pressure, as well as the temperature?

A. Yes, you must have a reference base.

Q. The higher temperature will make a difference in the pressure applied?

A. Yes, or conversely, the higher the pressure the higher the temperature must be.

Q. That is, the less pressure the lower the boiling point?

A. Yes.

Q. Can pentane exist as a gas in natural gas at a pressure lower than the boiling point if it were separated?

A. Pentane certainly can and does exist in gas at a temperature lower than its boiling point when you refer to that boiling point existing alone.

Q. Is that true of butane?

A. Yes, it is true of all of them.

By the Court:

State that again.

The Witness:

Mr. Speer asked if the pentane and butane or even some of the higher hydrocarbons could exist in the natural gas in the form of a gas when the temperature was lower than that corresponding to its boiling point, if the material existed alone. If the material existed alone, for instance its boiling point might be 37 deg. Centigrade in the case of pentane; now, the temperature of gas is much lower than that under normal conditions; it is about twenty. Now, at twenty degrees pentane would exist as a liquid under normal pressure; but when it exists in natural gas it exists as a gas. In other words, its pressure has been reduced and the boiling point has, therefore, been reduced so that if it is above the boiling point it must exist as a gas.

Q. In other words, in fixing the boiling point you must take pressure into consideration as well as temperature?

A. Yes.

Q. And when these are mixed together as they are in natural gas, what effect has that upon the atmospheric pressure?

A. Each gas present exists in proportion to the total pressure equal to its proportional volume.

Q. And as a result the pressure on each separate compound in that mixture is less?

A. If the specific gas comprises one per cent of the total mixture, the proportion of the total pressure exerted by the

whole gas mixture borne by this one per cent of the specific gas, is one per cent of the total pressure. This corresponds to Dalton's law of partial pressures.

Q. And as a result it will not liquefy until the temperature is lower?

A. Either that, or the pressure must be increased to the point corresponding to the lower boiling point.

Q. What is the atmospheric pressure here?

A. It is fourteen and four-tenths pounds to the square inch.

Q. If the particular hydrocarbon under consideration only formed a hundredth part of the gasoline mixture, what would the pressure be upon that particular hydrocarbon?

A. It would be fourteen hundred and forty pounds to the square inch in order to liquefy that proportion of gas that was in there.

Q. It would increase it a hundred times? A. Yes, for one per cent.

Q. Would it liquefy under that pressure until the pressure was increased a hundred times as long as it remained in the mixture?

A. No, not at that same temperature.

Q. Mr. Weymouth, you have heard the question asked Mr. Slicker as to the method they propose to use to remove the hydrocarbons which make up gasoline, he mentioning the absorption process; are you familiar with that process?

A. Yes, sir.

Q. Now, when that process is used, in what condition are these hydrocarbons pentane, hexane and heptane, before the process begins—in what condition are they?

A. They are gas.

Q. And after this process has been used what is made out of them?

A. They are then removed from the presence of the other gases and are condensed into liquid form.

Q. That is, at our ordinary temperature here? A. Yes.

CROSS-EXAMINED BY MR. MEHARD:

XQ. When you adopt this absorption method in treating the Alum Rock Gas Company gas, what would you expect would be the result in the form of gasoline, what do you think that gasoline would contain?

A. I think that gasoline contains propane, pentane, hexane and heptane and possibly some methane, possibly some of the higher hydrocarbons.

XQ. Mr. Weymouth, what would you say would be the form of these parts which you speak of as being gasoline, what would be their form under ordinary conditions of temperature and pressure?

A. As existing alone?

XQ. Yes.

A. Existing alone, everything above the butane is liquid.

XQ. Now, these other component parts that you speak of as making up natural gas, it would require a very high pressure, would it not—or an exceedingly low temperature to reduce them to a liquid?

A. Existing alone, yes.

XQ. If you were to treat the natural gas for the purpose of extracting gasoline would it be practicable for instance, take methane, what would you have to do to get methane into a liquid form?

A. You would have to reduce it to about minus 140 deg. fahr.

XQ. It would be an impracticable undertaking?

A. For methane, yes.

XQ. And the others that you have been speaking of, they would be correspondingly difficult to treat?

A. Yes, but they can exist in the gasoline, however, with a slight pressure.

XQ. How do you explain that?

A. Simply in the small proportions they would exist in the gasoline that would exert a very small pressure.

XQ. That would be in such proportions that they would hardly need to be reckoned with? A. Yes.

XQ. What I wish to know is whether the presence of gasoline in natural gas is desirable for light, heat or power, or whether the natural gas for uses of light, heat and power are better, the less gasoline there is in it.

A. I don't think anybody could say that the gas would be better by extracting the gasoline vapor from it.

XQ. Do you know what effect gasoline has on the flame where the burners are adjusted to the dry gas?

A. Yes, the gas doesn't usually have a sufficient amount of air to completely burn it, but where the burners are adjusted for the gas with the gasoline vapors in, you get just as perfect a combustion with a correspondingly higher heating effect of the flame.

XQ. To the extent of the loss of heat units that you have mentioned?

A. No, that does not apply to my answer. What I mean is: If you adjust your burners for the gas with the gasoline vapors in it, you will get just as perfect combustion as you do if the gas is leaner.

XQ. But where your burners are adjusted for the dry gas, then the gasoline would have what effect upon it?

A. It reduces the relative air proportions and it doesn't have quite enough air, but in the burners ordinarily commercially used, that effect is very scarcely noticed. I doubt if anybody here could notice it with the changes that are occurring in this gas.

XQ. Does the separation of the gasoline from natural gas diminish the quality of the gas in any appreciable degree for light, heat or power?

A. It is not a very large dimination. It is 2 per cent.

DR. O. J. SIEPLEIN.

Q. What is gasoline?

A. Gasoline is a light distillate from petroleum.

XQ. What is gas in its broad sense?

A. Gas in its broad sense is that form of matter which moves in space allotted to it.

Q. What is natural gas?

A. It is that gas which comes from the earth, combustible, as the term is generally used.

Q. Does gasoline ever occur in combination with natural gas? I wish you would define gasoline and answer this in your own way, so as to give us all the light you can.

A. As I stated in answer to a former question, gasoline, in my estimation, is the light distillate from petroleum. This gasoline may occur as vapor in natural gas when the natural gas has had an opportunity to be in contact with petroleum. It would of course be necessary that this petroleum be a gas-producing petroleum. The Pennsylvania petroleums are such, of course.

Q. Do you mean, doctor, that the gasoline vapor found in natural gas has been derived from contact with petroleum?

A. I do.

Q. Now, what form does gasoline take when that contact with petroleum has occurred and the combination has been made?

A. When contact with petroleum occurs?

Q. I will put it this way: What form does gasoline take when it is found in combination with natural gas?

A. The gasoline has become a vapor and mixed with the gas.

Q. Now, in what sense do you use the term vapor? What is meant by vapor as you use it?

A. As I use it, a substance which can be converted into a liquid by pressure alone; that is, gaseous substance.

Q. Do you make any distinction between vapor and gas in the broad sense of the word gas?

A. In the broad sense of the word gas, no.

Q. In the strict sense of the word gas, do you? A. I do.

Q. What distinction do you make?

A. The gas may not be converted to liquid by pressure alone, while a vapor may be converted to a liquid by pressure alone, the temperature remaining constant in all cases.

Q. What is the form of the component parts of gasoline at ordinary temperature and pressure?

A. At ordinary temperature and pressure the substances making up gasoline occur as liquid.

Q. Is there any other vapor usually found in combination with natural gas?

A. Water vapor.

Q. What is the combination between natural gas and gasoline, is it chemical or physical?

A. Physical.

Q. When gasoline is in the earth under ordinary conditions of temperature and pressure, what form would it take, that of gas or oil?

A. It is there as liquid, one of the portions of petroleum.

CROSS-EXAMINED BY MR. PARKER:

XQ. You have said that the hydrocarbons which go to make such gasolines that are produced from this gas, came off from petroleum; that is a mere matter of speculation?

A. If you call speculation the fact that such gases and petroleum are invariably produced by the same well, yes. If that is not speculation, no. As I am basing my answer, that is not speculation, from the fact that I know gas of this sort to be produced from wells which are also producing petroleum, and that gas that does not contain such vapors are produced from wells which do not produce petroleum.

XQ. And it is a fact that you find much less of these higher hydrocarbons in the wells that are producing no oil?

A. You find them virtually absent in most cases.

XQ. The fact, doctor, is this, is it not: that you have simply found those associated together?

A. I cannot answer that question if you insist upon the word "simply" in there.

XQ. Isn't it an accepted theory today, doctor, that the gas and the oil originated in the same strata?

A. That need not be true.

XQ. I will say suppose we have the third sand or another sand, you will find the oil at the lower elevation and the gas at the higher elevations in that particular formation?

A. Yes.

XQ. You find them associated together very largely?

A. You frequently find them associated together, but it is not necessary.

XQ. But in very indefinite relative proportions?

A. Everything from zero to either side.

XQ. You would not pretend to say that just the particular hydrocarbons, pentane, hexane, heptane and octane were the ones that came off from oil, would you?

A. I think we are justified in saying that.

XQ. And stopping right at that point?

A. No.

XQ. You do find in the earth the oil saturated with methane and ethane, do you not?

A. Occasionally.

XQ. That methane and ethane are not, as you understand it, constituents which ordinarily go to make gasoline?

A. No.

XQ. But you do find them in the oil?

A. All right.

XQ. You call those gases, don't you?

A. I do.

XQ. Isn't it a fact that it is a gas just in accordance with the state in which you find it?

A. The terms "gas" and "oil" are terms to describe the state.

XQ. They describe the state? A. Yes.

XQ. Of the same thing?

A. Absolutely.

XQ. When you find these hydrocarbons pentane, and hexane and up to octane in natural gas, they are actually a gas?

A. If you are using gas in a broad sense or in a narrow sense.

XQ. Don't all people call vapors gases, popular and scientific?

A. No, sir, scientifically we make a distinction between gas and vapors.

XQ. Are they both not gas?

A. They are both aeriform.

XQ. Describe gas.

A. A gas is a substance that can be converted to a liquid by pressure change only.

XQ. If you had oxygen below that particular point, above it, it wouldn't be a gas?

A. As long as you reach the critical point of oxygen it is a vapor; below that point it is a vapor.

XQ. Above that it is a gas?

A. Yes.

XQ. Do you mean to say it is a gas below?

A. It is a vapor below.

XQ. Isn't it a gas too?

A. If you are using gas in the narrow sense below the critical point it is a vapor.

XQ. Don't they say it is a gas, too?

A. No.

XQ. What authority can you produce that says that?

A. What?

XQ. That a vapor is not a gas.

A. Every authority will say that immediately you reach the critical temperature the gas laws do not apply to the same extent that they do above it.

BY MR. PARKER:

XQ. Doctor, what are the three states of matter?

A. Gaseous, liquid and solid.

XQ. You said yesterday afternoon that vapors and gases were all aeriform?

A. Gaseous substances.

XQ. You mean by that that they are gas?

A. Gaseous and aeriform bodies.

XQ. Gaseous and aeriform are practically synonymous as applied to matters of this kind?

A. Yes.

XQ. It is correct then—"Vapor above a liquid is a gas and hence exerts a pressure upon the bodies immersed in it"?

A. If you are using gas in a broader sense, yes.

XQ. That is, if you are using gas as a vapor?

A. Yes.

XQ. And this was used by men of the highest training?

A. Always with a reservation in mind.

XQ. What is the reservation?

A. The difference in changes due to temperature, pressure and volume variations.

XQ. That affects all matter?

A. No, not seriously. It affects all gaseous matter.

XQ. Don't you mean this, doctor, that there are points of demarcation between vapors and other gases? There is a line between vapors and other gases?

A. There is no line between vapors and other gases, an absolute line from a physical chemist's standpoint. If you mean in a popular sense, there is a broad line of demarcation.

XQ. Is this what you mean, doctor, that while water, for example, changes under ordinary conditions from a liquid

to a vapor at 100 deg. Centigrade, there may be changes at other points?

A. No, I don't mean that.

XQ. I mean that taking matter as a whole, there is no place where you can say: "Here vapor stops; here gases stop; and liquids begin"? That is, take all forms of matter or all varieties of matter, will that hold good for these hydrocarbons that you have stated?

A. No. Each individual substance is classified in one of these classes in a popular sense.

XQ. You wouldn't say when it is a gas and then convert it into a liquid or solid that it is still a gas, would you?

A. No. You raised the question of all varieties of substances and there is no line of demarcation you may draw there, but for any individual substance you may draw a line of demarcation between it as a gas, as a liquid or as a solid.

XQ. Is S. Lawrence Bigelow, Professor of general and physical chemistry in the University of Michigan, an authority? A. Yes.

XQ. Do you recognize his Theoretical and Physical Chemistry as authority?

A. Yes.

XQ Are you familiar with his statement of recent date in his book called "Theoretical and Physical Chemistry": "At one time a distinction was drawn between the terms gas and vapor. A substance in the gaseous state was called a vapor when below its critical temperature, and a gas when above it. There is no advantage to be derived from maintaining this old usage: water vapor above water at 20 deg. is a gas in all its properties just as much as the air in which it is dissolved."

A. I agree with that if you take into consideration that this book was written for the physical chemist and not for the layman.

XQ. You are testifying here as an interpreter of definitions in chemistry from the layman's standpoint and not from the expert's.

A. These terms have been used, from a popular standpoint.

XQ. You agree with this statement of Doctor Bigelow?

A. With the reservation that it is for the physical chemist, yes.

XQ. You made the statement yesterday, as I recall it, that vapors and gases did not follow the same rules, I believe, or the same laws?

A. Yes.

XQ. Is that correct?

A. Yes.

XQ. That does not agree with the statement we have just read from Bigelow?

A. Doesn't it?

XQ. I will read it to you again: "At one time a distinction was drawn between the terms gas and vapor. A substance in the gaseous state was called a vapor when below its critical temperature, and a gas when above it. There is no advantage to be derived from maintaining this old usage; water vapor above water at 20 deg. is a gas in all its properties just as much as the air in which it is dissolved."

A. Water vapor at 20 deg. would not follow the same laws accurately that the air above it does.

XQ. Then this statement of Doctor Bigelow's is not correct?

A. I mean that you are using a statement written for the physical chemist and not a statement written for common measure. There is a difference between the conception of the change of volume for temperature and pressure for the common measure and for the rigid measure, with the accuracy a few thousandths of one per cent.

XQ. Doctor Bigelow is writing from the standpoint of the scientist?

A. Yes, sir, for the scientists.

XQ. When you speak of these different properties that appear above and below the point at which vapor becomes a gas, from your standpoint what are the different laws that they observe there? I understand you to say they don't follow the same laws above and below the critical point.

A. Below the critical point you cannot postulate as you can above, that is with the accuracy of one-half of one per cent.

XQ. Isn't it true that any of your well-established laws with relation to gases only apply to perfect gas?

A. What do you mean by a perfect gas?

XQ. Does it exist at all?

A. No.

XQ. These laws don't follow out with this absolute accuracy that you have been talking about?

A. No.

XQ. It is true generally where you have a well-established principle it won't follow the law to a decimal point?

A. Laws are simply approximations anyway; that is, physical and chemical laws.

XQ. As you start away from the boiling point and rise, vapors and gases tend to approach nearer to these approximate laws laid down in chemistry and physics; as you leave the liquid state and rise toward the critical point don't they keep coming nearer and nearer to true laws?

A. Yes, sir.

XQ. And there is no well marked line of demarcation right at the critical point which says that vapors that obey the law below and gases obey the law above and disobey it below, but that is a gradual approach towards the perfect gas?

A. If you will take Mr. Bigelow's statement you will find that we obey the law. They are misnomers because the law describes the action or interprets the action; the matter goes on doing as it pleases.

XQ. None of them obey the law absolutely; they are only approximations?

A. Yes.

XQ. As you start from the liquid point and go up to the more gaseous state, they approach nearer to the law?

A. Yes sir.

XQ. But there is not any well-marked line that you draw right at the critical point which says that they obey or disobey these laws right at that point?

A. There is no well-marked line for any physical or chemical laws; that is, all physical or chemical laws.

XQ. Necessarily the first gas stage is a vapor stage, as you define the vapor?

A. Yes.

XQ. Then all matter as it leaves the liquid state and comes into the gaseous state and you keep on increasing the temperature first passes through this vapor stage?

A. Yes.

XQ. Consequently on the evaporation of any liquid the first thing we have is the vapor?

A. Yes sir.

XQ. That is what the public knows about it, isn't it? That is where the public sees it?

A. The public is basing on its own experience.

XQ. That vapor is gaseous as you have described it?

A. Yes.

Summary of Judge Criswell's Decision—"The requests for findings of facts in this case have been so carefully prepared by the learned counsel interested and so completely cover all material and pertinent facts involved, that

the same, with the answers thereto, are regarded as all that is necessary to a correct an intelligent disposition of the questions raised. For this reason no other or supplemental general findings as to facts are formulated. So likewise, the legal questions arising have been so clearly and fully suggested and indicated in the requests for legal conclusions that little can be added as supplemental to the answers thereto.

Stating it generally, the question involved is one concerning the proper construction of a contract for the sale of natural gas. Having reference to its particular facts it appears to be a case of the first impression in this state, if not generally. Because of its novelty, and its importance as well, and being a trial before the Court without the presence or aid of a jury, much latitude was permitted in the introduction of evidence pertaining to the special and related facts under consideration.

Particularly, the question is one as to the meaning of the terms "natural gas", it being contended on the part of the plaintiff that such terms, as used in its contract of purchase from the defendant, comprehend and mean such gas as it comes from the producing wells, including the hydro carbon compounds therein, which, being liquefied, constitute the commercial commodity known as gasoline, while the defendant's contention is that it may, under the terms of the contract, remove such hydrocarbon compounds from the gas before delivering the same to the plaintiff. The parties being thus at a direct disagreement relative to the meaning of the terms "natural gas," and the same being to a degree at least technical or trade terms, relating to a particular business, it was regarded as proper to hear evidence on the subject as to what was comprehended thereby. In so far as evidence was received not throwing light on this question it must be regarded as immaterial. If it was not proper to receive evidence on the subject, as

to the proper and definite meaning of said terms, the receipt thereof, and the findings derived therefrom, can predjudice no one, since the absence of any evidence on the subject, no conclusion is tenable other than that the plaintiff under the terms of its contract is entitled to the gas as it comes from the wells, and the facts found from the evidence harmonize with such finding.

So, regarding the contract, and there being no room for construction as to any other language therein, it is not subject to be in any way modified or overthrown by extrinsic proof relative to the circumstances under which it was made, the relation of the parties, or the object of the agreement.

No contention is here made that the contract is not valid and binding. Proof that the parties did not have in mind or contemplate the converting of any part of the gas into gasoline at the time the contract was entered into, was not made for the purpose of avoiding the contract, and, as offered in aid of construction, it is not material. If it is assumed that neither party so contemplated, it is not seen on what principle this fact would warrant a construction of the contract different from that which has been given it, or its terms impart.

Any allegation of mutual mistake would go to the validity of the contract as a whole. The admitted fact that the defendant did not so contemplate affords no basis, on any principle cited or known, for now granting it relief by giving to the contract a construction favorable to the defendant which it could not otherwise bear. The man who found treasure hidden in a field, and went and sold all that he had and bought the field appears to have had some conception of the binding effect of a contract, and of his right to stand on it. And so here, if the plaintiff's contract covers the gas as it comes from the wells including all the products and compounds therein contained, the defendants have no right to remove any of them before delivery to the plaintiff."

PART THREE

FIELD WORK

LEASING, DERRICK CONSTRUCTION, DRILLING, SHOOTING AND CARE OF GAS WELLS.

Fig. 30—A 40,000,000 FOOT GASSER

Lease—Almost the entire amount of gas and oil produced in the world is obtained from leased lands. The lease, therefore, which embodies in legal form the consideration, penalties and agreements between the land owner and the operator, is of fundamental importance, and should be a matter of record in the Recorder's office of the county in which the property is located. Leases of property owned or controlled by the Indians are under Federal supervision through the Department of Interior.

A lease may be obtained on a straight yearly rental basis, or, more commonly, on a basis of a specified amount for each gas well drilled in which gas in paying quantities is found. Likewise in event of finding oil in paying quantities the land owner generally receives a royalty of one eighth or one sixteenth of the total amount of oil produced from the property during the life of the wells.

In the lease the operator is generally given the exclusive right to drill for oil or gas, and a right of way for pipe line across the land.

Some leases stipulate that the farmer or land owner is to receive free gas for house use on the lease, but it is better that the operator install a domestic meter and require the land-owner to pay a reasonable price for the gas above a certain amount per month or per year. Leases granting free gas to the landowner have fallen into disfavor owing to the many abuses of the privilege and it is now the common custom to exclude the clause granting free gas privileges.

OIL AND GAS LEASE

AGREEMENT, Made and entered into the........................day of..................................
A. D., 191...., by and between..
....of...
County of.........................and State of........................, part........................of the first part
and ....
....the party of the second part.

WITNESSETH, that the said part........of the first part, for and in consideration of the sum of One Dollar to................in hand well and truly paid by the said party of the second part, the receipt of which is hereby acknowledged, and of the covenants and agreements herein contained on the part of the said party of the second part, to be paid, kept and performed, ha........granted, demised, leased and let, and by these presents do........grant, demise, lease and let unto the said party of the second part, its successors or assigns, for the sole and only purpose of mining and operating for oil and gas and of laying pipe, lines, and of building tanks, stations and structures thereon to take care of the said products, ALL that certain tract of land situate in the Town of....................County of................ and State of............, being part of Lot Number............bounded substantially as follows:
On the North by lands of..
On the East by lands of..
On the South by lands of..
On the West by lands of..
containing..acres, more or less, and being same land conveyed to the first part........by..by deed bearing date
..........................19........, reserving, however therefrom..
feet around buildings on which no wells shall be drilled by either party except by mutual consent, first part........also reserves from any well drilled on said premises under this lease gas sufficient for lighting and heating one dwelling house situate on said premises, when gas is produced and used therefrom; first part........to lay and maintain............own lines, burn said gas at............own risk with gas saving appliances subject to the approval of the lessee and assume responsibility for variation in pressures.

It is agreed that this lease shall remain in force for the term of ten years from this date, and as long thereafter as oil or gas, or either of them, is produced therefrom by the said party of the second part, its successors or assigns.

IN CONSIDERATION OF THE PREMISES the said party of the second part covenants and agrees as follows:

1st—To deliver to the credit of the first part........heirs or assigns, free of cost, in the pipe line to which it may connect its wells, the equal one-eighth ($\frac{1}{8}$) part of all oil produced and saved from the leased premises.

2nd—To pay........................Dollars per year for the gas from each and every gas well drilled on said premises, the product of which is marketed and used off the premises, said payment to be made on each well within sixty days after commencing to use the gas therefrom, as aforesaid, and to be paid yearly thereafter while the gas from said well is so used.

3rd—To locate all wells so as to interfere as little as possible with the cultivated portions of the farm.

4th—To commence a well on said premises within.. from the date hereof, or pay to the said part........of the first part thereafter in advance the sum of............................Dollars for each three months such commencement is delayed, and it is agreed that the commencement of a well shall be and operate as a full liquidation of all rental under this provision during the remainder of the term of this lease.

It is agreed that all payments under this lease shall be made to .... and may be made by cash or check, in hand, by deposit in .... Bank of ....or be mailed to...........address at............................P. O. .... County, State of..

....

....

....

....

....

....

It is agreed that the second party is to have the privilege of using sufficient water and gas from the premises to run all necessary machinery, and at any time to remove all machinery and fixtures placed on said premises; and further, upon the payment of One Dollar at any time to the part........of the first part........heirs, executors, administrators or assigns, said party of the second part, its successors or assigns, shall have the right to surrender this lease for cancellation, after which all payments and liabilities thereafter to accure under and by virtue of its terms shall cease and determine, and this lease become absolutely null and void. Such surrender and payment shall be made in the same manner as hereinbefore provided for the payment of rentals.

In Witness Whereof, the parties to this agreement have hereunto set their hands and seals the day and year first above written.

Witness

....(Seal)

....(Seal)

....(Seal)

....(Seal)

State of.. } ss.
County of.. }

On the............... day of.......................... A. D., 19........, before me the subscriber personally appeared..

....

to me known to be the person........described in, and who executed the foregoing instrument and acknowledged to me that.........executed the same.

....(Seal)

Notary Public in and for

.... County........................

State of.. } ss.
County of.. }

On this...............day of ....in the year 191........, before me personally came...................................subscribing witness to the within instrument, with whom I am personally acquainted, who being duly sworn, said that he resided in...............................that he was acquainted with..

....

and knew................to be the person........described in, and who executed the said instrument, and that he saw ....execute same, and that................acknowledged to him, the said...................................that...........................executed same, and that he thereupon subscribed his name as a witness thereto.

....

Notary Public in and for

.... County,........................

Well Location—In locating a well, consideration should be given to the water supply for the boiler, and to placing the boiler on the windward side of the derrick with reference to prevailing winds. In anticipating a large gasser, just prior to drilling in, the boiler should be moved to a safe distance.

Well Contract—The well contract is an agreement between the operator and the drilling contractor.

The contract is generally based on a certain price per foot of completed hole. In some cases the operator furnishes gas for fuel, in which case the contract should stipulate that the drilling contractor must use a boiler regulator to prevent extravagant waste of gas.

Derrick or Rig—There is a great variety of gas well drilling derricks or rigs, but all of them can be placed in two classes—standard and portable. Under the standard are the bolted steel or wood and the nailed derrick.

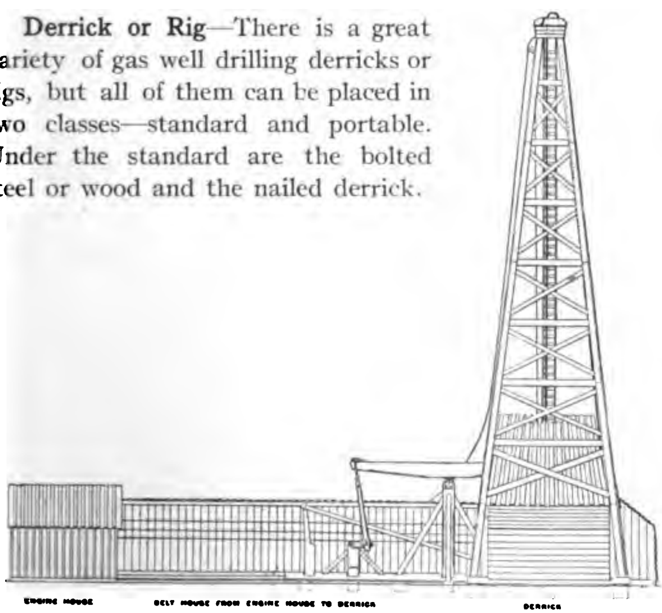


Fig. 31—CLOSED RIG

The lower part of the derrick is enclosed to protect the machinery and workmen from cold or stormy weather.

Structural steel derricks weigh about three-fourths as much as wooden derricks, this is because such pieces as a Samson post, Jack post, foundation sills etc., are made of steel and weigh much less than wood for the same pieces.

A steel derrick shows no signs of wear after being used a number of times, nothing to be replaced except wood or what may be carelessly lost.

The bolted design of wooden derrick is more expensive in the beginning but there is less waste in tearing down and putting up. A bolted wooden derrick should be painted and the bolts kept well oiled. The nailed derrick is the same style as the wooden bolted derrick except that the legs, girts and braces are spiked together in erecting.

A portable derrick has been used to drill a well 3000 feet deep but they are most commonly used in drilling wells less than 1000 feet deep. The height of a standard derrick is from 74 feet to 84 feet.

Fig. 32—PORTABLE DRILLING MACHINE

Fig. 33—CALIFORNIA DERRICK WITH PLATFORM

The laws of the State require the construction of platforms with railings around the derricks and the use of life belts when the drillers are working up in the derrick.

DERRICK AND DRILLING OUTFIT WITH ALL PARTS NUMBERED

1 Nose Sill
2 Mud Sills
3 Mud Sills
4 Main Sill
5 Sub Sill
6 Sand Reel Sill
7 Bumper, Engine Block to Main Sill
8 Engine Block
9 Engine Mud Sills
10 Derrick Mud Sills
11 Derrick Floor Sills
12 Foundation Posts
13 Bull Wheel Posts
14 Bull Wheel Shaft
15 Bull Wheel, Brake Side
16 Bull Wheel, Tug Side
17 Calf Wheel Posts
18 Calf Wheel Shaft
19 Calf Wheel
20 Skeleton Rim for Calf Wheel
21 Sand Reel Reach
22 Band Wheel Shaft
23 Iron Tug Wheel for Calf Wheel
24 Back Jack Post Box
25 Tug Pulley
26 Band Wheel
27 Front Jack Post Box and Cap
28 Shaft, Crank, Wrist Pin and Flanges
29 Iron Sand Reel
30 Sand Reel Posts
31 Jack Post
32 Pitman
33 Sand Reel Lever
34 Sampson Post
35 Sampson Post Braces
36 Derrick Crane Post
37 Headache Post
38 Walking Beam
39 Jack Post Brace
40 Derrick Ladder
41 Derrick Cornice
42 Derrick Girts
43 Derrick Braces
44 Bull Wheel Cants
45 Bull Wheel Arms

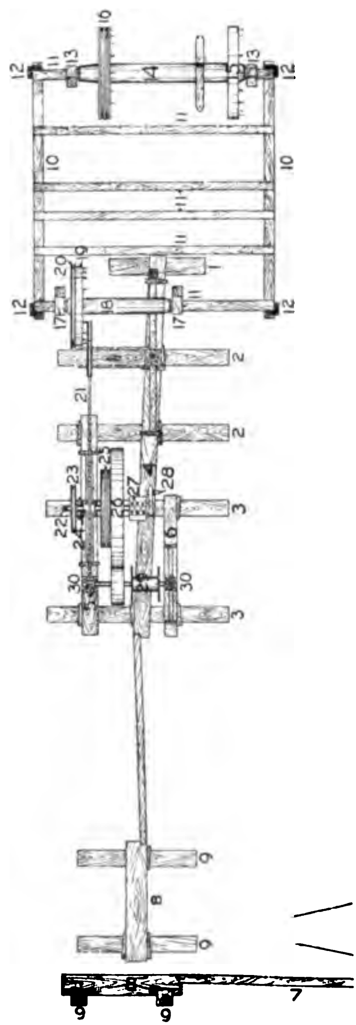


Fig. 34

DERRICK AND DRILLING OUTFIT WITH ALL PARTS NUMBERED—*Continued*

46 Calf Wheel Cants
47 Calf Wheel Arms
48 Belt
49 Adjuster Board
50 Derrick Floor
51 Bull Wheel Post Brace
52 Crown Pulley
53 Sand Pump Pulley
54 Casing Pulley
55 Sand Line
56 Drilling Cable
57 Casing Line
58 Bull Rope
59 Calf Rope
60 Temper Screw Elevator Rope
61 Temper Screw Pulleys
62 Center Irons
63 Stirrup
64 Calf Wheel Gudgeons (not visible)
65 Bull Wheel Gudgeons (not visible)
66 Brake Band for Bull Wheel
67 Brake Lever for Bull Wheel
68 Brake Staple for Bull Wheel
69 Sand Reel Hand Lever
70 Brake Lever and Staple for Calf Wheel
71 Brake Band for Calf Wheel
72 Telegraph Wheel
73 Derrick Crane with Chain Hoist and Swivel Wrench
75 Crown Block
76 Temper Screw
77 Rope Socket
78 Jars
79 Stem
80 Bit
81 Bailer or Sand Pump

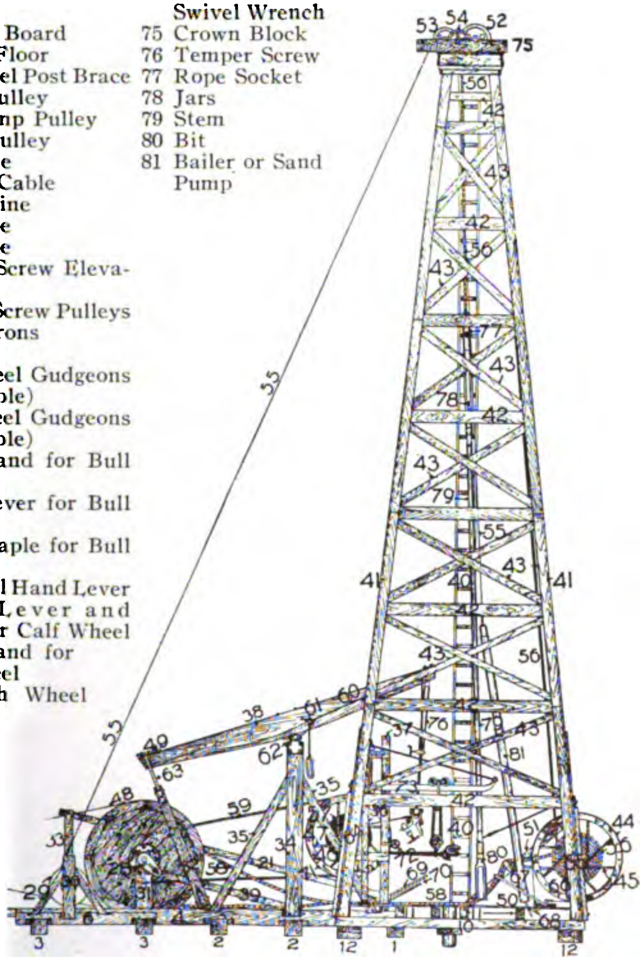


Fig. 35—(Continued)
NOTE:—Boiler and engine are not shown on this diagram

TABLE No. 21—SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A COMPLETE DOUBLE-TUG STANDARD RIG

NUMBERS REFER TO DRAWING ON PAGES 178 AND 179

Derrick 80 Feet High

No. in Diagram	No of Pieces	NAME OF PART Timbers: *Oak, Beech or Maple*	Size in Inches	Length in Feet
4	1	Main Sill	18x18	32
2	2	Mud Sills	16x16	16
3	2	Mud Sills	16x16	20
1	1	Nose Sill	16x16	8
5	1	Sub Sill	16x16	18
9	2	Engine Mud Sills	16x16	14
..	2	Engine Pony Sills	12x14	12
8	2	Engine Blocks	8x20	10
6	1	Sand Reel Sill	12x14	12
10–11	8	Derrick Sills	9x10	21
7	1	Bumper (engine to mudsills)	6x 8	24
..	1	Derrick Blocking	16x16	16
..	1	Dump Block	12x12	8
34	1	Sampson Post	16x16	16
31	1	Jack Post	16x16	12
39	2	Jack Post Braces	6x 8	16
35	4	Sampson Post Braces	6x 8	14
37	1	Headache Post	6x 8	16
13	2	Bull Wheel Posts	12x14	10
51	1	Bull Wheel Posts Brace	6x 8	14
17	1	Calf Wheel Post	12x14	10
30	1	Sand Reel Post	12x14	6
38	1	Walking Beam	14x24	26
..	3	Keys	3x 5	16
75	1	Crown Block	5x14	14
27	1	Jack Post Cap	5x14	5
30	1	Knuckle Post	5x14	8
33	1	Sand Reel Lever	9x11	10
32	1	Pitman Tapered	5x5–5x12	12
75	2	Sand Pully Block	2x12	20
..	2	Bull Wheel Spools	2x 6	20
..	2	Bull Wheel Spools	2x 4	16
69	1	Sand Reel Handle	2x 8	8
14	1	Octagon Bull Wheel Shaft	18x18 16x16	11
18	1	Octagon Calf Wheel Shaft	18x18 16x16	9
		Pine or Hemlock		
41	30	Derrick Legs, etc	2x 8	16
41	22	Derrick Legs, etc	2x10	16
..	6	Doublers	2x10	20
..	6	Starting Legs	2x 8	18
42	4	First Girts	2x12	18
42	4	Second Girts	2x10	18
43	8	First Braces	2x 6	20
43	14	Second Braces, etc	2x 6	18
..	30	Floor and Walk	2x12	20
40	20	Ladder and Stringers	2x 4	16
..	8	Engine House Stringer	2x 4	12
26	72	Band Wheel and Girts	1x12	16
43	60	Braces	1x 6	16
..	..	4000 Feet Boards	1	16
..	..	1000 Feet Boards	1	14
..	28	If Rig is to be Full Doubled	2x 8	16
..	12	If Rig is to be Doubled Front and Rear only	2x 8	16

SPECIFICATIONS—DOUBLE-TUG RIG—*Continued*

Outfit of Rig and Calf Irons, as follows:

FOUNDRY IRONS

Diagram No.	
28	1 Shaft, Crank, Wrist Pin and Collar.
28	1 Pair Flanges with Keys and Bolts.
62	1 Set Center Irons with Bolts.
52	1 Crown Pulley.
53	1 Sand Line Pulley.
63	1 Walking Beam Stirrup.
65	1 Pair Bull Wheel Gudgeons with Bands and Bolts.
24	1 Jack Post Box.
20	1 90-inch Skeleton Rim for Calf Wheel.
23	1 Iron Tug Wheel for Calf Wheel.
64	1 16-inch Bowl Calf Wheel Gudgeon with Band and Bolts.
64	1 30-inch Flange Calf Wheel Gudgeon with Band and Bolts.
54	2 Casing Pulleys.

BRAKE IRONS

Diagram No.	
66	1 Brake Band for Bull Wheel.
67	1 Brake Lever for Bull Wheel.
68	1 Brake Staple for Bull Wheel.
	1 Back Brake for Sand Reel if Wood Reel.
71	1 Brake Band for Calf Wheel.
70	1 Brake Lever for Calf Wheel.
70	1 Brake Staple for Calf Wheel.

WOODWORK

Diagram No.	
26	1 Set Band Wheel Cants.
25	1 Set Double Tug Pulley Cants.
44–45	1 Set Double Tug Bull Wheel Cants, Arms and Handles.
46–47	1 Set Calf Wheel Cants, Arms and Handles.

Diagram No.

29 SAND REEL: 1 Wood Sand Reel or 1 Iron Sand Reel with Lever and Straps.

NAILS, BOLTS AND WASHERS

150 pounds 10d Nails.
150 pounds 20d Nails.
150 pounds 30d Nails.
4 ¾x8-inch Machine Bolts.
8 ¾x9-inch Machine Bolts.
3 ¾x10-inch Machine Bolts.
10 ¾x12-inch Machine Bolts.
4 ¾x14-inch Machine Bolts.
4 ¾x16-inch Machine Bolts.
11 ¾x18-inch Machine Bolts.
6 ¾x20-inch Machine Bolts.
2 ¾x22-inch Machine Bolts.
4 ⅞x12-inch D. E. Bolts with 2-inch Square Nuts.
6 ⅞x22-inch D. E. Bolts with 2-inch Square Nuts.
58 ¾-inch Wrought Iron Washers.
58 ¾-inch Cast Iron Washers.
10 ⅞-inch Cast Iron Washers.
1 piece 1½-inch Pipe 18 inches long.

NOTE—The above Bolts and Washers are in addition to those furnished with the Foundry Rig Irons.

Estimated shipping weight of complete specifications as shown on this and preceding page, including rig irons and lumber, 78,000 pounds

TABLE No. 22—SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA RIG

Derrick 82 Feet High with 20 Foot Base, Using Standard Rig Irons

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Walking Beam	12x12x12x26	26	676
1	Engine Block	22x22	9	363
1	Main Sill	16x16	30	640
1	Sub-Sill	16x16	20	427
1	Sampson Post	16x16	16	341
1	Select Bull Wheel Shaft	16x16	14	299
1	Select Calf Wheel Shaft	16x16	6	128
4	Mud Sills	14x14	16	1045
1	Tail Sill and Post	14x14	16	261
1	Nose Sill and Jack Post Cap	14x14	16	261
2	Engine Mud Sills	14x14	14	458
2	Casing Sills	14x14	12	392
1	Jack Post	14x14	12	196
1	Back Brake and Blocking	12x12	20	240
2	Bull Wheel and Calf Wheel Post	10x12	24	480
1	Bumper	10x12	14	140
2	Pony Sills	10x12	12	240
2	Side Sills	8x8	22	234
11	Derrick Sills, Casing Rack and Blocking	8x8	20	1177
1	Bunting Pole	6x6	26	78
1	Dead Man	6x6	20	60
2	Jack Post Braces	6x6	18	108
1	Calf Wheel Brace	6x6	16	48
5	Back Brake, Headache Post Sampson Post and Bull Wheel Braces	6x6	14	210
5	Calf Wheel and Short Braces	4x6	16	160
2	Select Crown Blocks	5x16	16	214
1	Knuckle Post	5x16	12	80
2	Pitman and Swing Lever	5x5x5x14	12	140
14	Band Wheel (surface one side)	2x12	20	560
54	Derrick Foundation Floor, Walk and Girts	2x12	20	2160
8	Derrick Foundation and Girts	2x12	18	288
8	Girts and Top of Derrick	2x12	16	256
4	Girts	2x12	14	112
6	Starting Legs and Belt House Sills	2x10	26	258
28	Doublers	2x10	24	1120
20	Derrick Legs and to cut up	2x10	16	540
12	Derrick Roof, Forge and Belt House	2x8	18	288
4	Starting Legs	2x8	18	96
20	Derrick Legs and to cut up	2x8	16	420
1	Bunting Pole to Jack Post	2x8	24	32
5	Belt House	2x6	26	130
17	Braces	2x6	20	340
8	Braces	2x6	18	144
12	Braces and to cut up	2x6	16	192
2	Engine House	2x6	14	28
3	Engine House	2x6	12	36
20	Ladders and to cut up	2x4	16	220
3	Engine House	2x4	14	27
3	Engine House	2x4	12	24
30	Boarding up	1x12	20	600
75	Boarding up	1x12	18	1350
146	Girts and Boarding up	1x12	16	2336

SPECIFICATIONS—CALIFORNIA RIG—*Continued*

No of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
50	Engine House Siding and Boarding up	1x12	14	700
60	Boarding up	1x12	12	720
60	Braces and Ladders Strips	1x6	16	480
	Total Oregon Pine			22,553
	Hardwood			
1	Oak Top of Crown Block	4x5	16	27
1	Oak Top of Crown Block	4x5	14	23
1	Oak Top of Beam and Dog	2x12	16	32
	Total Hardwood			82

CANTS—SINGLE TUG

56 1x8-inch Plain for 10-foot Band Wheel.
8 2½x8-inch Grooved for 8-foot Bull Wheel.
8 2½x8-inch Plain for 8-foot Bull Wheel.
72 1x8-inch Plain for 8-foot Bull Wheel.
8 2½x8-inch Plain for 7½-foot Calf Wheel.
40 1x8-inch Plain for 7½-foot Calf Wheel.
8 2½x8-inch Plain for 7-foot Tug Pulley.
8 2½x8-inch Grooved for 7-foot Tug Pulley.
16 1x8-inch Plain for 7-foot Tug Pulley.
32 lineal feet 1½-inch O. P. Round B. W. Handles.
1 Hardwood Follower.
24 O. P. Rig Keys.

NAILS, BOLTS, WASHERS, ETC.

50 pounds 60d Nails.
100 pounds 40d Nails.
100 pounds 30d Nails.
100 pounds 20d Nails,
150 pounds 10d Nails.
2 ¾x38-inch Bolts.
2 ¾x32-inch Bolts.
1 ¾x30-inch Bolt.
1 ¾x24-inch Bolt.
2 ¾x22-inch Bolts.
4 ¾x20-inch Bolts.
12 ¾x18-inchBolts.
20 ¾x16-inch Bolts.
16 ¾x14-inch Bolts.
14 ¾x12-inch Bolts.
8 ¾x10-inch Bolts.
5 ¾x 8-inch Bolts.
4 ¾x26-inch D. E. Bolts.
1 piece 1½-inch Round Iron 16 inches long.
6 1½-inch Cast Iron Washers.
20 1-inch Cast Iron Washers.
25 1-inch Wrought Iron Washers.
125 ¾-inch Cast Iron Washers.
100 ¾-inch Wrought Iron Washers.
1 600-foot Coil Guy Wire.

RIG IRONS: 1 Complete Set Rig and Calf Wheel Irons.

BRAKE IRONS: 1 Complete Set Bull Wheel and Calf Wheel Brake Irons.

SAND REEL: 1 Single or Double Drum Sand Reel with Cast Iron or Steel Flanges with Lever.

TABLE No. 23
SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALIFORNIA COMBINATION STANDARD AND ROTARY RIG
Derrick 102 Feet High with 22 Foot Base, Using Standard Rig Irons

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
4	Mud Sills	16x16	16	1365
2	Mud Sills	16x16	20	853
1	Sampson Post	16x16	16	341
1	Jack Post	16x16	16	341
1	Tail Sill	16x16	16	341
1	Sub Sill	16x16	20	427
1	Main Sill	16x16	32	683
1	Nose Sill and Back Brake	14x14	16	261
2	Pony Sills	14x14	12	392
2	Engine Blocks	22x22	9	726
1	Walking Beam	14x14x30	26	910
1	Calf Wheel Post	12x12	26	312
1	Bull Wheel Post	12x12	22	264
2	Jack Sills	14x14	22	719
1	Top Derrick	12x12	13	156
1	Bunting Pole	6x8	30	120
1	Headache Post	6x8	16	64
1	Back Brake Sill	6x8	10	40
2	Sampson Posts	6x6	16	96
4	Braces	4x6	20	160
6	Braces	4x6	16	192
4	Braces	4x6	14	112
4	Arms, Surface 4 sides	3x12	18	216
2	Arms, Surface 4 sides	3x12	16	96
22	Band Wheel, Surface 1 side	2x12	16	704
9	Band Wheel, Surface 1 side	2x12	22	396
9	Band Wheel, Surface 1 side	2x12	20	360
3	Derrick	2x8	24	96
1	Pitman	6x6x16	14	112
1	Swing Lever	6x6x16	12	96
2	Belt House	2x6	26	52
2	Belt House	2x6	24	48
2	Belt House	2x6	22	44
10	Braces	2x6	20	200
3	Engine House	2x6	14	42
2	Engine House	2x6	12	24
4	Engine House	2x4	12	32
20	Derrick	1x8	16	213
30	Belt House	1x8	20	400
50	Engine House and Derrick	1x12	16	800
35	Engine House and Derrick	1x12	14	490
90	Belt House	1x12	20	1800
12	Belt House	1x12	24	288
2	Derrick	12x12	24	576
7	Derrick	10x10	22	1283
4	Derrick	8x8	20	427
4	Derrick	2x10	26	173
4	Derrick	2x10	18	120
63	Derrick	2x10	16	1680
4	Derrick	2x12	24	192
4	Derrick	2x12	22	176
4	Derrick	2x12	20	160
4	Derrick	2x12	18	144
8	Derrick	2x12	16	256
8	Derrick	2x12	14	224
8	Derrick	2x12	12	192
10	Derrick	2x12	10	200

SPECIFICATIONS—COMBINATION STANDARD AND ROTARY RIG—*Continued*

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
7	Derrick....................	2x6	24	168
8	Derrick....................	2x6	22	176
8	Derrick....................	2x6	20	160
16	Derrick....................	2x6	18	288
8	Derrick....................	2x6	16	128
18	Derrick....................	2x8	16	384
16	Derrick....................	2x8	14	299
4	Doublers..................	2x12	18	144
2	Doublers..................	2x12	20	80
56	Doublers..................	2x12	22	2464
4	B. W. Arms S. 4 S..........	2½x10	18	150
2	C. W. Arms S. 4 S..........	2½x12	16	80
4	Band Wheel S. 1 S..........	2x12	18	144
4	Sway Braces................	2x12	22	176
4	Sway Braces................	2x12	20	160
4	Sway Braces................	2x12	18	144
4	Sway Braces................	2x12	16	128
4	Sway Braces................	2x12	14	112
8	Sway Braces................	2x10	28	373
16	Sway Braces................	2x10	26	693
8	Sway Braces................	2x10	24	320
8	Sway Braces................	2x10	22	293
	Total Oregon Pine, feet..			28,251
	Redwood			
16	Corners....................	3x12	20	960
	Hardwood			
1	Bull Wheel Shaft, Oak.......	16x16	14	299
1	Calf Wheel Shaft, Oak.......	16x16	6	128
2	Crown Block, Oak...........	6x6	12	72
1	Crown Block, Oak...........	6x6	6	18
1	Crown Block, Oak...........	2x12	6	12
1	Crown Block, Oak...........	6x16	16	128
2	Crown Block and Post.......	6x16	14	224
	Total Hardwood, feet...			881

NAILS, BOLTS, WASHERS, ETC.

100 pounds 60d Nails.
200 pounds 30d Nails.
200 pounds 20d Nails.
200 pounds 10d Nails.
2 ¾x10-inch Bolts.
22 ¾x12-inch Bolts.
10 ¾x14-inch Bolts.
20 ¾x16-inch Bolts.
45 ¾x18-inch Bolts.
6 ¾x20-inch Bolts.
2 ¾x24-inch Bolts.
2 ¾x28-inch Bolts.
3 ¾x30-inch Bolts.
2 ¾x42-inch Bolts.
168 ¾-inch Cast Iron Washers.
18 1-inch Cast Iron Washers.
84 ¾-inch Wrought Iron Washers.
24 1-inch Wrought Iron Washers.
1 600-foot Coil ⅜-inch Guy Wire.

CANTS—SINGLE AND DOUBLE TUG

For specifications of cants see specifications for regular and heavy California rigs on preceding page.

RIG IRONS: One complete Set Rig and Calf Wheel Irons.

BRAKE IRONS: 1 Complete Set Bull Wheel and Calf Wheel Brake Irons.

1 Single or Double Drum Sand Reel with Cast Iron or Steel Flanges with Lever.

Fig. 36—STEEL CROWN BLOCK
Weight, 1200 lbs.

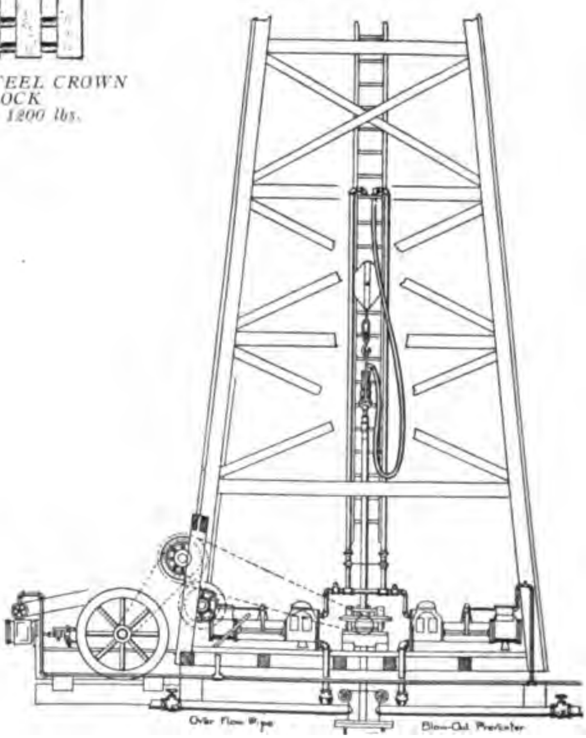


Fig. 37—HYDRAULIC ROTARY RIG

TABLE No. 24
SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALFORNIA HEAVY RIG

Derrick 82 Feet High with 20 Foot Base, Using Ideal Rig Irons

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Select Beam	14x14x14x30	26	910
1	Engine Block	22x24	9	396
1	Main Sill	16x16	30	640
1	Sub Sill	16x16	20	427
1	Sampson Post	16x16	16	341
1	Jack Post	16x16	14	299
1	Select Bull Wheel Shaft	16x16	14	299
6	Rig and Engine Mud Sills	14x14	16	1566
1	Tail Sill and Post	14x14	16	261
1	Blocking	14x14	20	327
2	Casing Sills	14x14	14	458
3	Pony Sills and Nose Sill	14x14	12	588
2	Bull and Calf Wheel Posts	12x12	24	576
1	Back Brake and Blocking	12x12	20	240
1	Bumper	12x12	14	168
1	Bunting Pole	8x8	26	139
2	Side Sills	8x8	22	234
11	Derrick Sills and Casing Rack and Blocking	8x8	20	1177
2	Dead Men	6x6	20	120
2	Jack Post Braces	6x6	18	108
1	Calf Wheel Brace	6x6	16	48
5	Back Brake, Headache Post, Sampson Post and Bull Wheel Braces	6x6	14	210
5	Calf Wheel and Short Braces	4x6	16	160
2	Select Crown Blocks	6x16	16	256
1	Knuckle Post	5x16	12	80
1	Select Pitman	6x6x6x16	12	96
1	Select Swing Lever	5x5x5x14	12	70
4	Select S. 4 S. to 2½x11-inch Bull Wheel Arms	3x12	18	216
2	Select S. 4 S. to 2½x11-inch Calf Wheel Arms	3x12	16	96
14	S. 1 S. Band Wheel	2x12	20	560
54	Derrick Foundation Floor, Walk and Girts	2x12	20	2160
8	Derrick Foundation and Girts	2x12	18	288
8	Girts and Top of Derrick	2x12	16	256
4	Girts	2x12	14	112
28	Doublers	2x12	24	1344
6	Starting Legs and Belt House Sills	2x10	26	258
4	Short Starting Legs	2x10	18	120
48	Derrick Legs and to cut up	2x10	16	1296
1	Bunting Pole to Jack Post	2x8	24	32
12	Derrick Roof, Forge and Belt House	2x8	18	288
5	Belt House	2x6	26	130
17	Braces	2x6	20	340
8	Braces	2x6	18	144
12	Braces and to cut up	2x6	16	192
2	Engine House	2x6	14	28
3	Engine House	2x6	12	36
20	Ladders and to cut up	2x4	16	220
3	Engine House	2x4	14	27
3	Engine House	2x4	12	24
30	Boarding up	1x12	20	600
75	Boarding up	1x12	18	1350

SPECIFICATIONS—CALIFORNIA HEAVY RIG—*Cont.*

No. of Pieces	Name of Part *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
146	Girts and Boarding up........	1x12	16	2336
50	Engine House Siding, Derrick Roof and Boarding up......	1x12	14	700
60	Boarding up................	1x12	12	720
60	Braces and Ladder Strips.....	1x6	16	480
	Total Oregon Pine......	....	....	24,547
	Hardwood			
1	Oak Calf Wheel Shaft........	16x16	6	128
1	Oak Top of Crown Block.....	5x6	16	40
1	Oak Top of Crown Block.....	5x6	14	35
1	Oak Top of Beams and Dog..	2x12	16	32
	Total Hardwood.......	....	....	235
	**Oregon Pine*			
4	Girts......................	2x12	18	144
4	Girts......................	2x12	16	128
4	Girts......................	2x12	14	112
2	Girts......................	2x12	20	80
8	Braces.....................	2x8	22	235
8	Braces.....................	2x8	20	213
8	Braces.....................	2x8	18	192
8	Braces.....................	2x8	16	171
	Total..................	....	....	1,275

*Note—If outside girts and braces are wanted, add the following.

CANTS—DOUBLE TUGS

56 1x8-inch Plain for 10-foot Band Wheel.
16 2½x8-inch Grooved for 8-foot Bull Wheel.
8 2½x8-inch Plain for 8-foot Bull Wheel.
80 1x8-inch Plain for 8-foot Bull Wheel.
8 2½x8-inch Plain for 7½-foot Calf Wheel.
40 1x8-inch Plain for 7½-foot Calf Wheel.
24 O. P. Rig Keys.
16 2½x8-inch Grooved for 7-foot Tug Pulley.
8 2½x8-inch Plain for 7-foot Tug Pulley.
24 1x8-inch Plain for 7-foot Tug Pulley.
32 lineal feet 1½-inch O. P. Round B. W. Handles.
1 Hardwood Follower.

NAILS, BOLTS, WASHERS, ETC.

50 pounds 60d Nails.
100 pounds 40d Nails.
100 pounds 30d Nails.
100 pounds 20d Nails.
150 pounds 10d Nails.
2 ¾x42-inch Bolts.
2 ¾x32-inch Bolts.
1 ¾x30-inch Bolt.
1 ¾x30-inch Bolt.
1 ¾x26-inch Bolt.
1 ¾x24-inch Bolt.
2 ¾x22-inch Bolts.
4 ¾x20-inch Bolts.
26 ¾x18-inch Bolts.
12 ¾x16-inch Bolts.
10 ¾x14-inch Bolts
25 ¾x12-inch Bolts.
1 ¾x10-inch Bolts.
2 ¾x8-inch Bolts.
4 ⅞x28-inch D. E. Bolts.
1 piece 1½-inch Round Iron, 16 inches long.
2 1½-inch Cast Iron Washers.
20 1-inch Cast Iron Washers.
25 1-inch Wrought Iron Washers.
130 ¾-inch Cast Iron Washers.
100 ¾-inch Wrought Iron Washers.
1 600-foot Coil Guy Wire.

IDEAL RIG IRONS: 1 Complete Set 5 or 6-inch Ideal Rig and Sprocket Calf Wheel Irons.

BRAKE IRONS: 1 Set Bull Wheel and Calf Wheel Brake Irons.

SAND REEL: 1 Double Drum Sand Reel with Steel Flanges with Lever.

TABLE No. 25
SPECIFICATIONS OF MATERIAL REQUIRED TO BUILD A CALFORNIA ROTARY RIG

Derrick 106 Feet High with 24 Foot Base

No. of Pieces	NAME OF PART *Oregon Pine*	Size in Inches	Length in Feet	Total Feet
1	Engine Block	22x24	9	396
2	Mud Sills	14x14	16	522
2	Pony Sills	14x14	12	392
1	Blocking	14x14	20	327
2	Casing Sills	14x14	24	784
1	Blocking	12x12	20	240
1	Bumper	12x12	14	168
2	Side Sills	10x10	26	434
8	Derrick Sills	8x8	24	1024
4	Casing Sills and Blocking	8x8	20	428
2	Dead Men	6x6	20	120
6	Pump Foundations	6x6	18	324
2	Select Crown Block	6x16	16	96
72	Floor Girts and Doublers	2x12	24	3456
8	Girts	2x12	22	352
4	Girts	2x12	20	160
8	Girts	2x12	18	288
4	Girts	2x12	16	128
23	Derrick Foundation and Top	2x12	20	920
12	Derrick Foundation	2x12	18	432
4	Starting Legs	2x10	26	172
4	Starting Legs	2x10	18	120
54	Derrick Legs	2x10	16	1458
4	Top of Derrick	2x10	18	120
8	First Set Braces	2x8	24	256
8	Second Set Braces	2x8	22	232
8	Third Set Braces	2x8	20	216
8	Fourth Set Braces	2x6	20	160
8	Fifth Set Braces	2x6	18	144
8	Sixth Set Braces	2x6	16	128
30	Ladders and to cut up	2x4	16	330
50	Boarding up	1x12	24	1200
75	Boarding up	1x12	20	1500
50	Boarding up	1x12	16	800
70	Braces and Ladder Strips	1x6	16	560
	Total Oregon Pine			18,387
	Hardwood			
1	Oak Top of Crown Block	5x6	16	40
1	Oak Top of Crown Block	5x6	14	35
	Total Hardwood			75

NAILS, ETC.—100 pounds 40d Nails, 100 pounds 30d Nails, 100 pounds 20d Nails, 100 pounds 10d Nails, 2—600-foot Coils Guy Wire.

CARE OF WIRE LINES

In oiling wire lines it is better to use a compound or oil that is not too heavy. Heavy oils cling to the outer side of the cable and do not penetrate to the inner strands or the hemp center. A medium oil when properly applied will penetrate and cover not only inner strands but the hemp.

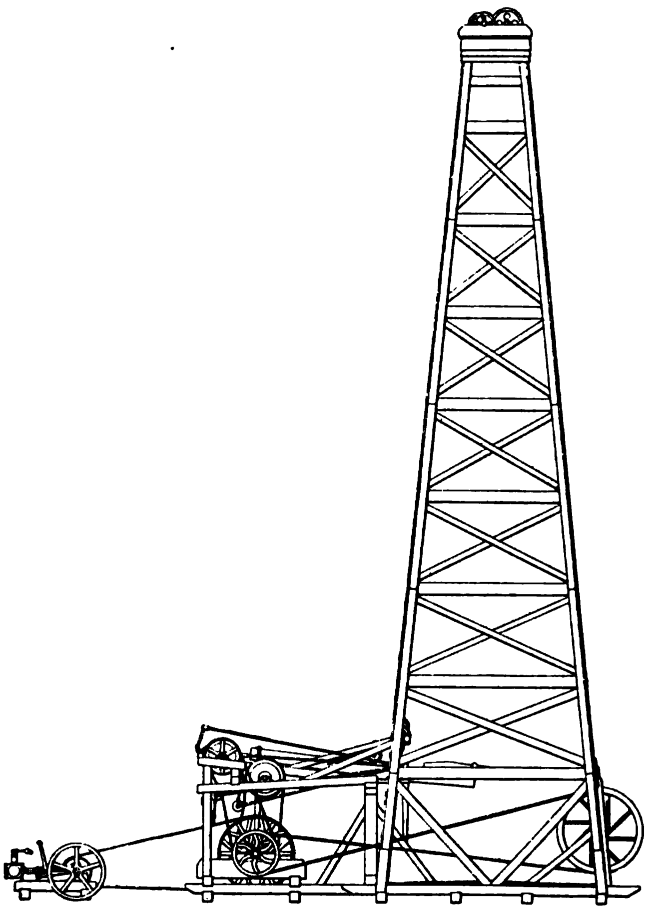


Fig. 38—POLE TOOL RIG (CANADIAN)

TABLE No. 26—DRILLING LINES

LEFT LAY

Composed of 6 Strands and a Hemp Center, 19 Wires to the Strand.

EXTRA STRONG CAST STEEL

Diameter in Inches	Approximate Circumference in Inches	Approximate Weight Per Foot	Approximate Strength in Tons of 2000 Pounds	Diameter of Drum or Sheave in Feet Advised
1⅛	3½	2.00	43	4½
1	3	1.58	34	4
⅞	2¾	1.20	26	3½
¾	2¼	.89	20.2	3
⅝	2	.62	14	2½
CAST STEEL				
1⅛	3½	2.00	38	4½
1	3	1.58	30	4
⅞	2¾	1.20	23	3½
¾	2¼	.89	17.5	3
⅝	2	.62	12.5	2½

These lines are designed to be exceedingly flexible and elastic, and are consequently especially adapted for deep wells, where the rope is directly attached to tools by a swivel socket.

Composed of 6 Strands and a Hemp Center, 7 Wires to the Strand.

EXTRA STRONG CAST STEEL

1⅛	3½	2.00	43	8
1	3	1.58	35	7
⅞	2¾	1.20	28	6
¾	2¼	.89	21	5
11/16	2⅛	.75	16.7	4¾
⅝	2	.62	14.5	4½
CAST STEEL				
1⅛	3½	2.00	37	8
1	3	1.58	31	7
⅞	2¾	1.20	24	6
¾	2¼	.89	18.6	5
11/16	2⅛	.75	15.4	4¾
⅝	2	.62	13.	4½

A manila "cracker," spliced to the end of the line next the tools, is frequently used with this construction. The large wires of this line are especially adapted to withstand abrasion encountered in drilling through sand. It is also used for cleaning out.

TABLE No. 27—PUMPING LINES

LEFT LAY

6 Strands and a Hemp Center, 7 Wires to the Strand.

EXTRA STRONG CAST STEEL

Diameter in Inches	Approximate Circumference in Inches	Approximate Weight Per Foot	Approximate Strength in Tons of 2000 Pounds	Diameter of Drum or Sheave in Feet Advised
7/8	2 3/4	1.20	28.0	6
3/4	2 1/4	.89	21.0	5
11/16	2 1/8	.75	16.7	4 3/4
5/8	2	.62	14.5	4 1/2
9/16	1 3/4	.50	11.0	4
1/2	1 1/2	.39	8.85	3 1/2

CAST STEEL

7/8	2 3/4	1.20	24.0	6
3/4	2 1/4	.89	18.6	5
11/16	2 1/8	.75	15.4	4 3/4
5/8	2	.62	13.0	4 1/2
9/16	1 3/4	.50	10.0	4
1/2	1 1/2	.39	7.7	3 1/2

TABLE No. 28—SAND LINES

CAST STEEL

Composed of 6 Strands and a Hemp Center, 7 Wires to the Strand.

5/8	2	.62	13.0	4 1/2
9/16	1 3/4	.50	10.0	4
1/2	1 1/2	.39	7.7	3 1/2
7/16	1 1/4	.30	5.5	3
3/8	1 1/8	.22	4.6	2 3/4

SUCKER ROD LINES

CAST STEEL—RIGHT LAY

6 Strands of 19 Wires Each—Hemp Center.

1/2	1 1/2	.39	8.4	2
7/16	1 1/4	.30	6.5	1 3/4
3/8	1 1/8	.22	4.8	1 1/2

TABLE No. 29

CASING OR TUBING LINES

CAST STEEL—RIGHT LAY

Composed of 6 Strands and a Hemp Center, 19 Wires to the Strand.

Diameter in Inches	Approximate Circumference in Inches	Approximate Weight Per Foot	Approximate Strength in Tons of 2000 Pounds	Diameter of Drum or Sheave in Feet Advised
1¼	4	2.45	47.0	5
1⅛	3½	2.00	38 0	4½
1	3	1.58	30.0	4
⅞	2¾	1.20	23.0	3½
¾	2¼	.89	17.5	3
⅝	2	.62	12.5	2½
9/16	1¾	.50	10.0	2¼
½	1½	.39	8.4	2

BLUE CENTER STEEL

1¼	4	2.45	69.0	5
1⅛	3½	2.00	56.0	4½
1	3	1.58	45.0	4
⅞	2¾	1.20	35.0	3½
¾	2¼	.89	26.3	3
⅝	2	.62	19.0	2½
9/16	1¾	.50	14.5	2¼
½	1½	.39	12.1	2

RIGHT LAY

Composed of 6 Strands and a Hemp Center, 19 Wires to the Strand.

EXTRA STRONG CAST STEEL

1¼	4	2.45	53.0	5
1⅛	3½	2.00	43.0	4½
1	3	1.58	34.0	4
⅞	2¾	1.20	26.0	3½
¾	2¼	.89	20.2	3
⅝	2	.62	14.0	2½
9/16	1¾	.50	11.2	2¼
½	1½	.39	9.2	2

CASING OR TUBING LINES—*Continued*

PLOUGH STEEL

Diameter in Inches	Approximate Circumference in Inches	Approximate Weight Per Foot	Approximate Strength in Tons of 2000 Pounds	Diameter of Drum or Sheave in Feet Advised
$1\frac{1}{4}$	4	2.45	58.0	5
$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	47.0	$4\frac{1}{2}$
1	3	1.58	38.0	4
$\frac{7}{8}$	$2\frac{3}{4}$	1.20	29.0	$3\frac{1}{2}$
$\frac{3}{4}$	$2\frac{1}{4}$	.89	23.0	3
$\frac{5}{8}$	2	.62	15.5	$2\frac{1}{2}$
$\frac{9}{16}$	$1\frac{3}{4}$	.50	12.3	$2\frac{1}{4}$
$\frac{1}{2}$	$1\frac{1}{2}$	.39	10.0	2

DEAD LINES

RIGHT LAY

6 x 19 Splicing Endless. Length after Splicing.

Made in sizes of $1\frac{1}{4}$-in., $1\frac{1}{8}$-in. and 1-in.—40ft. and 50-ft. lengths. These lines also furnished with loop spliced in each end.

SPLICING SETS

$\frac{3}{4}$-INCH ROPE AND SMALLER

Two $3\frac{1}{2}$-inch wooden mallets.
One hickory stick, 1 inch diameter, $2\frac{1}{2}$ feet long.
One No. 4 rubber knife.
One 5-foot endless $1\frac{1}{2}$-inch circumference manila rope.
One pair 12-inch Carew cutters.
Two 9 x $\frac{5}{16}$-inch splicing pins.
Two 8 x $\frac{1}{4}$-inch splicing pins.

$\frac{5}{8}$-INCH TO $1\frac{1}{8}$-INCH ROPE

Two $3\frac{1}{2}$-inch wooden mallets.
One hickory stick, $1\frac{1}{4}$ inch diameter, $2\frac{1}{2}$ feet long.
One No. 4 rubber knife.
One 6-foot endless, 2-inch circumference, manila rope.
One pair 12-inch Carew cutters.
Two T-shaped pins, 7 inches long.
One 12 x $\frac{7}{8}$-inch taper spike.
Two 9 x $\frac{5}{16}$-inch splicing pins.

TABLE No. 30—MANILA ROPE

Long Fibre Pure Manila* Three Strand—After a long series of tests the Bureau of Standards adopted the following standards for Manila Rope.

Diameter in Inches	Circumference in Inches	Approx. Gross Weight of a 1200-ft. Coil	Net Weight Per Foot Rope	Breaking Strength in Pounds
3/16	1/2	20 (40) *	.0166	550
1/4	3/4	24 (40) *	.0196	700
5/16	1	35 (55) *	.0286	1,200
3/8	1 1/8	50 (65) *	.0408	1,450
7/16	1 1/4	66 (80) *	.0539	1,750
1/2	1 1/2	90	.0735	2,450
9/16	1 3/4	126	.1029	3,150
5/8	2	160	.1307	4,000
3/4	2 1/4	198	.1617	4,900
13/16	2 1/2	234	.1911	5,900
7/8	2 3/4	270	.2205	7,000
1	3	324	.2645	8,200
1 1/16	3 1/4	378	.3087	9,500
1 1/8	3 1/2	432	.3528	11,000
1 1/4	3 3/4	504	.4115	12,500
1 5/16	4	576	.4703	14,200
1 3/8	4 1/4	648	.5290	16,000
1 1/2	4 1/2	720	.5879	17,500
1 9/16	4 3/4	810	.6615	19,500
1 5/8	5	900	.7348	21,500
1 3/4	5 1/2	1080	.8818	25,500
2	6	1296	1.059	30,000
2 1/16	6 1/2	1500	1.225	34,000
2 1/4	7	1764	1.441	38,500
2 1/2	7 1/2	2016	1.646	43,500
2 5/8	8	2304	1.881	49,000
2 7/8	8 1/2	2580	2.107	55,000
3	9	2916	2.381	61,000
3 1/8	9 1/2	3240	2.645	67,000
3 1/4	10	3600	2.940	73,000

* The five smallest sizes are manufactured to weights approximately the same as the figures in parenthesis above, on account of making convenient coils for handling.

6 thread fine	(1/2-in. Cir.)—3/16-in.	Diameter
6 thread	(3/4-in. Cir.)—1/4-in.	Diameter
9 thread	(1 -in. Cir.)—5/16-in.	Diameter
12 thread	(1 1/8-in. Cir.)—3/8-in.	Diameter
15 thread	(1 1/4-in. Cir.)—7/16-in.	Diameter
18 thread	(1 3/8-in. Cir.)—7/16-in. full	Diameter
21 thread	(1 1/2-in. Cir.)—1/2-in.	Diameter
24 thread	(1 5/8-in. Cir.)—1/2-in. full	Diameter
27 thread	(1 3/4-in. Cir.)—9/16-in.	Diameter
30 thread	(1 7/16-in. Cir.)—9/16-in. full	Diameter

To find the number of feet in one pound of rope divide the one pound by the figure in the table under the heading "Net Weight per Foot Rope."

For example, what is the number of feet in one pound of three-stranded Rope $\frac{9}{16}$ in. diameter? Divide one pound by .1029 (weight of one foot) which equals 9.71 feet. To reduce .71 feet to inches multiply it by twelve, which equals 8½ inches. Therefore the number of feet in one pound of $\frac{9}{16}$ in. Rope is 9 feet 8½ inches.

Standard full coils approximately 1200 ft. (200 fathoms).

Standard half coils approximately 600 ft. (100 fathoms).

Bull Wheel—The Bull Wheel is the large wheel on the derrick floor on which is coiled the manila or wire line used in drilling.

The first American saw mills used the wheel to haul logs out of the water to the saw. It was first known as the "pull wheel," but from its strength the word was changed to "bull wheel."

Fig. 41—CABLE SYSTEM OF DRILLING
Showing Derrick Floor, Bull Wheel, Temper Screw, etc.

Bull Rope—The "Bull Rope" acts as a belt between the band wheel and the "bull wheel." It probably takes its name from the "bull wheel." It is generally made from a piece of the drilling cable of a two or two and one-half inch manila rope.

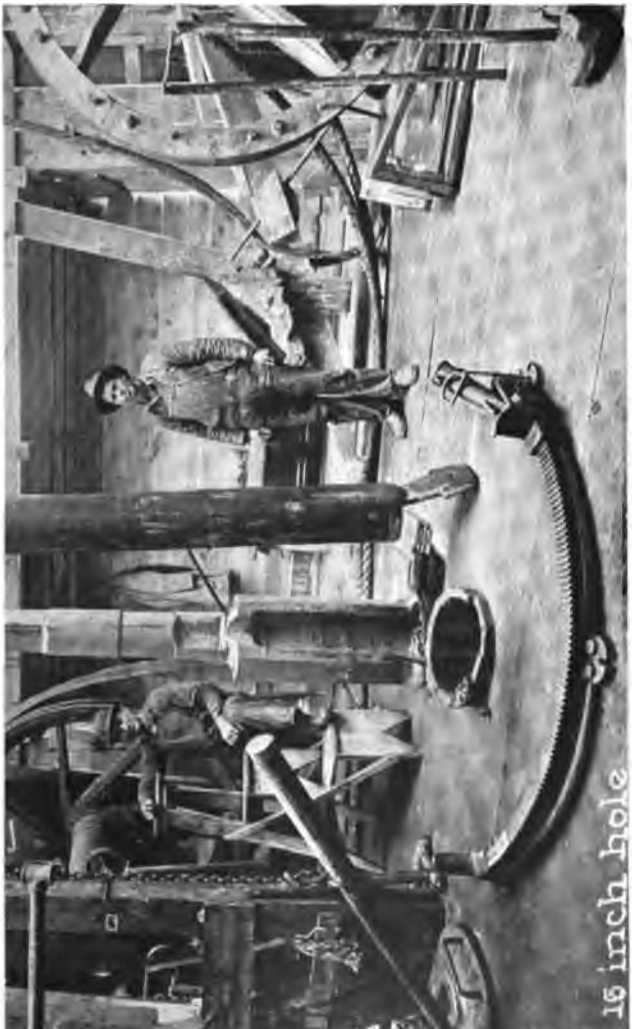


Fig. 42—DRILLING OUTFIT
Showing Stem, Bit and Bailer

Walking Beam—The Walking Beam is as old as prehistoric times. It was originally the "working beam" but the name was changed to "walking beam," probably through the peculiar motion resembling walking. It was used by the Egyptians and was known as "Shadoof," a device for raising water from the Nile for irrigation purposes. In this country it is familiarly known as the "well sweep." The first steamships used it and called it the "walking beam."

Drilling—Wells vary in depth from 200 feet to 7000 feet. Very shallow wells are from two to sixteen inches in diameter. Deep gas wells start with a ten inch hole, or larger, depending on the formation, and finish with a hole from four and seven-eighths inches to six and one-quarter inches in diameter.

The hole is reduced in size only when it becomes necessary to set a string of casing to exclude water, each reduction being after the casing is put in, after which the well is allowed to stand long enough to determine whether the hole has been cased dry or not.

The casing should extend beyond the flow of water. Often a steel shoe is used on the bottom of drive pipe or casing. This makes the casing tight at the bottom and less apt to leak, but on the other hand, it is harder to pull the casing afterward.

In event of the casing leaking after being set, wheat or rice can be put in on the outside of the casing and oftentimes will stop the leakage. Where there is no water directly beneath the gas vein, the well should be drilled about 25 feet deeper, thus forming a pocket for the accumulation of sand and cave-ins.

Where there is water underneath the gas sand and the sand is shallow, do not drill over one screw into the sand. If the sand is deep, two or more screws are sufficient.

TABLE No. 31—DRIVE PIPE

Nominal Inside Diameter Inches	Thickness Inch	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
3	0.217	7.54	8	$4\frac{1}{8}$
4	0.237	10.66	8	$5\frac{1}{4}$
6	0.280	18.76	8	$7\frac{1}{2}$
8	0.322	28.18	8	$9\frac{19}{32}$
8	0.363	32.00	8	$9\frac{19}{32}$
10	0.366	40.06	8	$11\frac{31}{32}$
12	0.375	49.00	8	$13\frac{31}{32}$
14	0.375	58.00	8	$16\frac{7}{16}$

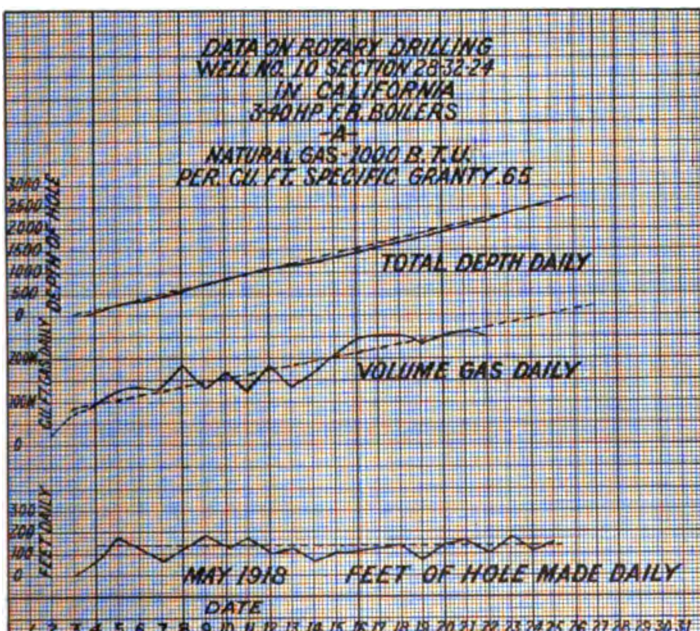


Fig. 43—CHART SHOWING VOLUME OF GAS USED AS FUEL IN DRILLING AT DIFFERENT DEPTHS IN THE MIDWAY FIELD, CALIFORNIA

TABLE No. 32

The following data compiled from the books of the Hope Natural Gas Company, through the courtesy of John B. Corrin, Vice President of that Company, reveals a practically proportionate increase of drilling and operating costs in the West Virginia gas fields, and these would be equally applicable to Pennsylvania, and Ohio:

WEST VIRGINIA COSTS OF DRILLING AND OPERATING GAS WELLS

HOPE NATURAL GAS COMPANY

Statement Showing Actual Cost of Well 2880, Complete in June 1913, and the Estimated Cost of Same Well if Completed in Each Year Following

	Feet In.	1913 Cost	1914 Cost	1915 Cost	1916 Cost	1917 Cost	1918 Cost	1919 Cost
Rig Timbers	....	$ 75.00	$100.00	$100.00	$100.00	$100.00	$121.32	$125.00
Lumber for New Rig	11,850—½	343.65	355.50	379.20	414.75	414.75	414.75	367.35
Labor for Building Rig	....	150.00	159.38	159.38	178.13	206.25	206.25	225.00
Rig Parts or Irons	....	117.58	115.15	116.62	217.50	217.50	278.32	232.75
Hauling	....	226.75	226.75	226.75	247.75	288.65	329.81	329.81
Freight & Miscellaneous	....	23.69	23.69	25.70	27.00	30.00	32.00	30.00
TOTAL RIG	....	$936.67	$980.47	$1,007.65	$1,185.13	$1,257.15	$1,382.45	$1,309.91
Drilling	3,422—	4,106.40	4,106.40	4,106.40	4,619.70	5,304.10	5,646.30	6,672.90
Labor	....	1,035.96	1,105.03	1,105.03	1,197.11	1,427.33	1,519.42	1,611.51
Teaming	....	907.00	907.00	907.00	989.00	1,152.00	1,320.00	1,320.00
Freight	....	6.03	6.03	6.03	6.03	6.03	6.03	6.03
Miscellaneous	....	492.93	542.22	591.51	665.44	739.39	813.33	788.71
Use of Casing Pulled	2,895	289.50	289.50	289.50	289.50	289.50	289.50	289.50
Torpedoes	....	115.50	115.50	115.50	140.50	177.00	227.50	227.50
....		$6,953.32	$7,071.68	$7,120.97	$7,907.28	$9,095.35	$9,822.08	$10,916.15
CASING								
10 in.	894— 5	554.28	668.22	654.88	1,764.13	1,764.13	1,824.13	1,519.66
8¼ in.	1,530— 2	850.78	772.73	757.27	2,096.31	2,096.31	2,295.24	2,035.11
6⅝ in.	2,173— 8	965.30	885.76	885.76	2,412.76	2,412.76	2,651.86	2,369.29
4 in.	2,825	639.95	639.95	639.95	792.97	1,871.56	2,048.12	1,829.18
3 in.	206— 3	23.89	23.89	27.62	27.62	98.48	97.97	87.14
2 in.	856— 5	100.14	100.14	100.14	229.11	229.11	278.36	199.13
		$3,134.34	$3,090.69	$3,065.62	$7,322.90	$8,472.35	$9,195.68	$8,039.51
Other Equipment	....	71.73	71.73	71.73	143.46	143.46	150.00	135.00
TOTAL	....	$11,096.06	$11,214.57	$11,265.97	$16,558.77	$18,968.31	$20,550.21	$20,400.57

COMPARISON OF WAGES PAID

	1917	1919		1917	1919
Assistant Foreman	$100.00	$155.00	C. O. T. Drillers per Month	$130.00	$150.00
Drillers per Day	7.00	9.00	C. O. T. Dressers "	110.00	130.00
Tool Dressers "	6.00	8.00	Rousters per Day	3.10	3.50
			Teamsters "	3.00	4.00

TABLE No. 33

The following table showing the cost of drilling Oklahoma oil wells and operating the same is clipped from a recent issue of the Oil and Gas Journal, and shows in a striking way the rapid advances in drilling and operating costs for oil wells, and of course, the same is true for gas wells:

OKLAHOMA DRILLING AND OPERATING COSTS

	1913	1914	1915	1916	1917	1918	1919
Lumber for Rig	$ 460.00	$ 506.00	$ 552.00	$ 667.00	$ 839.50	$ 1,069.50	$ 1,200.00
Contract Price for Building Rig	175.00	175.00	175.00	200.00	210.00	250.00	300.00
Complete Rig Irons	405.35	383.00	304.60	481.60	636.10	683.00	700.00
Contract Drilling 2,500 Feet	2,025.00	3,375.00	3,650.00	4,375.00	5,000.00	5,625.00	7,750.00
Contract Day Labor	800.00	850.00	900.00	1,000.00	1,200.00	1,375.00	1,800.00
Gas Engine House	140.00	150.00	145.00	145.00	165.00	200.00	300.00
Gas Engine and Setting	615.00	615.00	615.00	685.00	935.00	1,200.00	1,500.00
Tanks and Tank Houses	830.00	875.00	850.00	900.00	1,200.00	1,500.00	1,750.00
Miscellaneous Material	650.00	725.00	800.00	900.00	1,080.00	1,200.00	1,500.00
Other Well Labor	276.00	314.00	296.00	296.00	395.00	500.00	750.00
Setting Gas Engine	100.00	105.00	100.00	100.00	115.00	125.00	175.00
Miscellaneous Labor	139.00	158.00	149.00	149.00	178.00	225.00	275.00
Hauling	185.00	210.00	199.00	199.00	237.00	300.00	500.00
Casing, Rods and Tubing (Including Working Barrels)	5,025.66	4,867.54	4,822.42	6,544.45	9,256.77	10,323.70	13,000.00
Total for Complete Well	$12,726.01	$13,308.54	$13,648.02	$16,642.05	$21,447.37	$24,576.20	$31,500.00

TABLE No. 34—SIZES OF CASING

Nominal Inside Diameter Inches	Outside Diameter Inches	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
2	2¼	2.16	14	2.687
2¼	2½	2.75	14	2.875
2½	2¾	3.04	14	3.187
2¾	3	3.33	14	3.500
3	3¼	3.96	14	3.781
3¼	3½	4.28	14	4.000
3½	3¾	4.60	14	4.250
3¾	4	5.47	14	4.625
4	4¼	5.85	14	4.687
4¼	4½	6.00	14	4.937
4¼	4½	9.00	14	4.937
4½	4¾	6.55	14	5.218
4½	4¾	9.00	14	5.218
4¾	5	7.58	14	5.562
5	5¼	8.00	14	5.781
5	5¼	10.00	14	5.781
5	5¼	13.00	11½	5.781
5	5¼	17.00	11½	5.781
5 3/16	5½	8.40	14	6.062
5 3/16	5½	13.00	11½	6.062
5⅝	6	10.16	14	6.062
5⅝	6	12.00	11½	6.625
5⅝	6	14.00	11½	6.625
5⅝	6	17.00	11½	6.625
6¼	6⅝	11.50	14	7.125
6¼	6⅝	13.00	11½	7.125
6¼	6⅝	17.00	11½	7.125
6⅝	7	12.45	14	7.687
6⅝	7	17.00	10	7.687
7¼	7⅝	13.50	14	8.220
7⅝	8	15.00	11½	8.625
7⅝	8	20.00	11½	8.625
8¼	8⅝	16.00	11½	9.312
8¼	8⅝	20.00	11½	9.312
8¼	8⅝	24.00	8	9.312
8⅝	9	17.50	11½	9.750
9⅝	10	21.00	11½	10.812
10⅝	11	23.00	11½	......
11⅝	12	25.15	11½	......
12½	13	35.75	11½	......
13½	14	42.02	11½	......
14½	15	47.66	11½	......
15½	16	51.47	11½	......

Fig. 44—GETTING READY TO "SHUT IN" A BIG GASSER

Fig. 46—ROTARY SYSTEM IN TEXAS

TABLE No. 35

WEIGHT OF WATER IN PIPE OF DIFFERENT DIAMETERS IN LENGTHS OF ONE FOOT

62.425 POUNDS PER CUBIC FOOT

The following table will be found useful in computing the weight of water in a string of pipe or casing in a well.

Diameter Inches	Water Pounds	Diameter Inches	Water Pounds	Diameter Inches	Water Pounds
1	.3405	5	8.5119	10½	37.537
1⅛	.4309	5¼	9.3844	11	41.198
1¼	.5320	5½	10.299	11½	45.028
1⅜	.6437	5¾	11.257	12	49.028
1½	.7661	6	12.257	12½	53.199
1⅝	.8997	6¼	13.300	13	57.540
1¾	1.0427	6½	14.385	13½	62.052
1⅞	1.1970	6¾	15.513	14	66.733
2	1.3619	7	16.683	15	76.607
2⅛	1.5375	7¼	17.896	16	87.162
2¼	1.7237	7½	19.152	17	98.397
2½	2.1280	7¾	20.450	18	110.31
2¾	2.5748	8	21.990	19	122.91
3	3.0643	8¼	23.174	20	136.10
3¼	3.5963	8½	24.599	21	150.15
3½	4.1708	8¾	26.068	22	164.79
3¾	4.7879	9	27.579	23	180.11
4	5.4476	9¼	29.132	24	196.11
4¼	6.1498	9½	30.728	25	212.80
4½	6.8946	9¾	32.366	26	230.16
4¾	7.6820	10	34.048	27	248.21
				28	266.93

Water Pressure—The pressure of still water in pounds per square inch against the sides of any pipe or vessel of any shape is due alone to the head or height of the surface of the water above the point pressed upon, and is equal to 0.434 pounds per square inch for every foot of head, the fluid pressure being equal in all directions. For example: the pressure in pounds per square inch at the bottom of well tubing 1,000 feet deep and filled with water would be 0.434 × 1,000 = 434 pounds pressure.

Fig. 46—LARGE GAS WELL NEAR HOUMA, LA. JUST BEFORE CAPPING

CAPPING A LARGE GAS WELL

Figures 46 to 48 show a novel method of capping a large gas well. In this instance the derrick was practically destroyed by the flow of the gas. A track was laid to the well with one rail coming on either side of it. A small flat car was constructed to carry considerable weight. After this work was completed a gate and nipples put together were securely held in place in front of the car by a superstructure on it. The car was then weighed down with two inch tubing. The nipples on the gate passed through a sleeve as shown in figure 48 so that the entire connection could be screwed on to the casing of the well by the aid of a steel line and pulled by men at a distance from the well.

The noise of the gas was terrific. The men were compelled to use cotton in the ears covered with soap then covered with bandages. All instructions were given by signs as one's voice could not be heard within any reasonable distance of the well. When everything was ready the car with its load of pipe to hold it to the rails, carrying the gate and nipples set up, was moved forward and the gate and nipples was started on the casing by aid of a wire line. After same was caught a few threads, chain tongs were applied and the gate was set up properly. During the entire operation the gate valve was left open and was not closed until it was securely screwed on to the casing. Following this operation other gate valves were placed above the master gate and the gas was controlled mainly by them. The gas carried considerable sand and when a gate valve was partially opened the volume of gas was so great and the pressure so high that gate valves did not last very long.

Fig. 47—SAME AS FIG. 48, SHOWING CARRIAGE BEING FORCED FORWARD OVER THE FLOWING GAS FROM THE WELL

Fig. 48—SAME WELL AS IN FIG. 47 AFTER BEING CAPPED

MIDWAY'S MIDNIGHT SUN*

An enormous torch blazing 200 feet into the air recently gave evidence of unusual new activity in the north end of the Midway field.

On July 26, 1919, the Company's Hay No. 7 well, on section 36, township 30 south, range 23 east, Elks Hills

Fig. 49—MIDWAY'S MIDNIGHT SUN

District, suddenly leaped to life while being drilled, and gassed so furiously that it set itself ablaze in a flame that could be seen for eighty miles and the roar of which could be

*Courtesy of the Standard Oil Bulletin published at San Francisco, Calif.

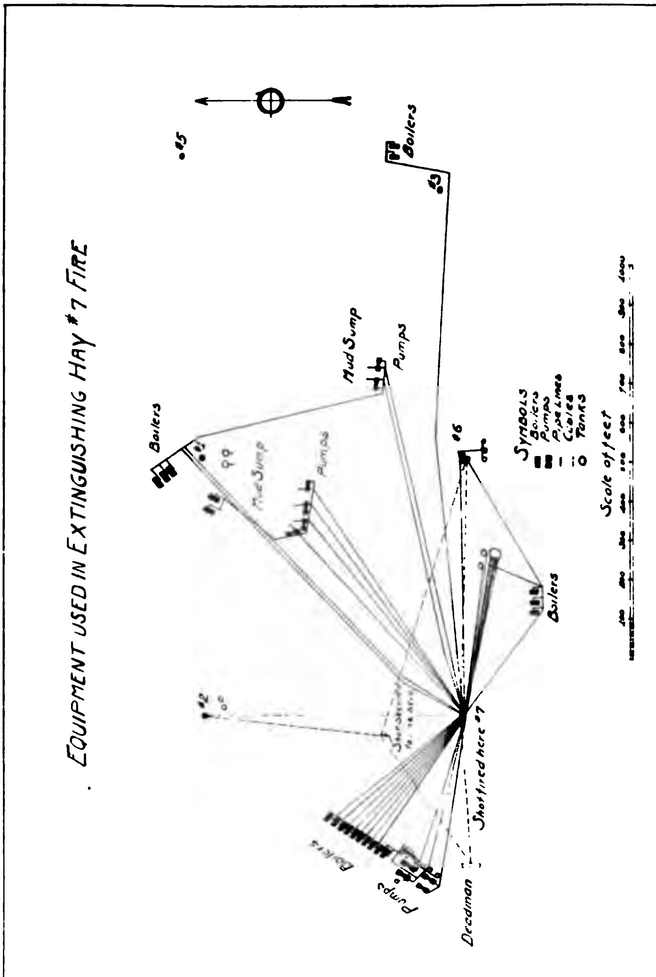

EQUIPMENT USED IN EXTINGUISHING HAY #7 FIRE
Boilers
#2
Mud Sump
Pumps
Mud Sump
Pumps
#5
Boilers
#3
#6
Boilers
#2
Shot fired here #7
Deadman
Pumps
Symbols
Boilers
Pumps
Pipe Lines
Cables
Tanks
Scale of feet
1000

Fig. 50

heard for nine miles, thus constituting the largest gas fire in the history of California and one of the largest in the United States. Two previous wells on the same property had come in as gassers, but their flow was considerably less than that of No. 7, which was estimated at about 100,000,000 cubic feet per day.*

The well was drilling with a rotary at 2135 feet in 10-inch casing, the 12½ and 10-inch strings of casing having been landed, when what appeared to be water-sand was encountered. To test this sand for water, the mud was bailed out to relieve the pressure and allow any water present to accumulate in the hole. During the course of bailing the well blew out and the enormous flow of gas began. The top of the 12½-inch casing was equipped with a heavy gate-valve and a 6-inch flow-line which extended to the side of the derrick. The drilling crew attempted to get the well under control by closing the 12½-inch gate-valve, but the shale and sharp sand carried by the stream of gas cut out the seat of the valve while it was being closed. This gate having failed, there was no alternative to letting the well blow until more fittings could be attached. After blowing for an hour the drillers said that the 6-inch flow-line became red hot for two feet at its end, due to the friction of the shale and sand on the pipe, and ignited the enormous stream of gas.

By means of the usual methods of steam, mud and water, the fire was extinguished for fifty feet from the ground, but the gas continued to burn above the effective zone of steam and water, as the boilers could not maintain sufficient pressure long enough to prevent the gas from the well breaking through to the flame above. The heat from the flame was so intense that in order to get the fire-fighting equipment close enough to be effective the men had to work behind metal shields and under showers of water from 3-inch lines.

* Some experienced gas men made a series of tests that indicated a volume of approximately 187,000,000 cubic feet per day. If correct, this well is the largest gasser ever known.

Fig. 51—GETTING READY TO CONNECT HAY No. 7

Fig. 52—HAY No. 7 WELL CONNECTIONS AFTER EXTINGUISHING FIRE

The manager of the producing department, two colonels of the United States Army and the superintendent of the Midway District, were at the scene of the fire. The army officers considered the advisability of using a 6-inch army field-piece for snuffing out the blaze, but decided that the flame was too large for the use of such a gun. At this point the division superintendent suggested the use of dynamite, his theory being that after the steam, mud and water had subdued the lower flames the concussion of the dynamite

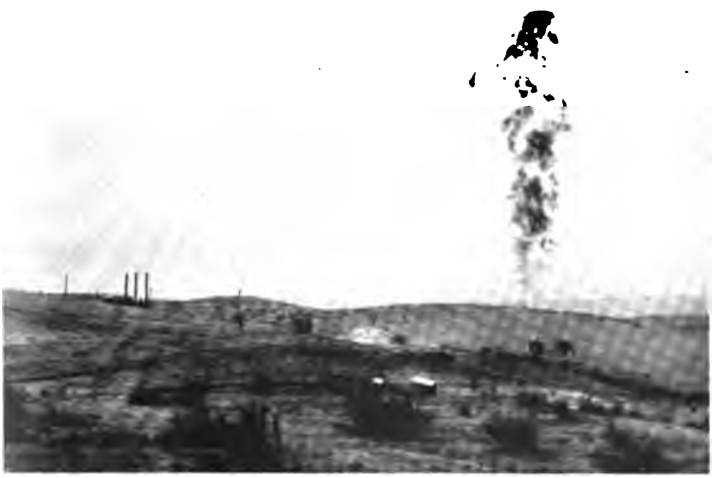


Fig. 53—HAY No. 7

would break the stream of gas long enough to allow the flames at the top to burn out before the intercepted stream of gas from the well could again reach them. This plan seemed so feasible that it was tried out, in connection with the use of large streams of carbon tetrachloride, on the morning of August 5th. When the charge of dynamite was exploded there was a deep-red glow, a black puff, and the big fire was out.

The equipment used, which is shown diagrammatically on page 212, consisted of 20 boilers, 21 three-inch lines, 9 four-inch lines, 13 pumps, several large tanks, 100 barrels of carbon tetrachloride and 150 pounds of dynamite.

Well Record—A complete and accurate record or log of the well while drilling should be kept by either the contractor or the field man. All formations and known sands should be shown with their proper names. The depth of finding oil, gas, or water, and a statement of the thickness of the sands, with an opinion of the quality of the sand, should be included in the report.

Fig. 64—SHOWING ONE BATTERY OF BOILERS USED IN EXTINGUISHING THE FIRE

Shooting—Shooting consists of exploding a charge of nitroglycerin in the well on a level with the gas vein, the object being to fracture the gas-bearing rock to allow a more free movement of the gas from the gas sand to the well proper.

Fig. 65

During the process of drilling, accurate measurements should be taken with a steel measuring line, showing the depth of the sand, the thickness of same, and the amount of pocket below the sand. If the sand is hard and the well under 1,000,000 cu. ft. capacity per day, eighty quarts of nitroglycerin is the proper shot, and for soft sand with the same size flow, forty quarts. In wells of larger flow than 1,000,000 cu. ft. per day, it is not advisable to shoot on account of the danger in lowering the shell into the well. The shot should be placed on top of the proper amount of tin tubing anchorage, the length of the latter being determined by the log of the well previously taken. The main body of the shot should rest opposite the sand where there is no water vein directly underneath the sand, one shell should be placed below the bottom of the sand to enlarge the pocket for the accumulations of cave-ins, sand, etc.

Fig. 66—STEEL LINE FOR MEASURING DEPTH OF WELL

Note brake lever hanging from shaft, also weight, hanging on line, which keeps line taut while in use and assists in finding bottom.

In shooting a gas well, the operator should be well versed as to the character of the sand, as some gas wells are liable to be ruined by shooting.

Nitroglycerin—Nitroglycerin is a heavy, oily, explosive liquid $C_3 H_5 (NO_3)_3$. The color varies from water white to amber, obtained by treating glycerin with a mixture of nitric and sulphuric acids. It produces by detonation about fourteen thousand times its own volume of gas. Compared with gunpowder it is eight times as powerful,

Fig. 57—WELL SHOOTER AND OUTFIT FOR USE IN ROUGH COUNTRY

weight for weight, or thirteen times as powerful, volume for volume. It is shipped in ten quart cans and transported from factory to field by wagon or automobile.

Nitroglycerin freezes at about 45 degrees fahr. and must be thawed before lowering into the well for shooting. It is a very dangerous explosive to handle as it requires due care and skill to prevent a premature explosion.

Before shooting, any water or oil in the well should be bailed out until the level of same is below any casing. If

the water or oil should reach up above the bottom of the casing a shot would injure it unless the casing is lifted off its seat.

After shooting, the empty cans should be exploded at a safe distance either by use of a fuse and a percussion cap or by shooting at them with a rifle.

Solidified Nitroglycerin—This explosive is made by putting nitroglycerin through a process whereby its nature is changed from liquid to a gelatinous substance about the consistency of soft putty, but more rubber like. It is four per cent more powerful than liquid nitroglycerin, weight for weight. It is somewhat insensitive as compared to the liquid—this being necessary to have it comply with the Interstate Commerce Commission regulations. The color varies with the color of the nitroglycerin used in its manufacture.

Fig. 58—PREPARING SOLIDIFIED NITROGLYCERIN TO LOAD INTO SHELL FOR SHOOTING GAS WELL

Solidified nitroglycerin is put up in round sticks, wrapped with paper similar to dynamite, and is packed in small boxes. It can be shipped by freight to point of destination. This is a great advantage over the liquid nitroglycerin as it eliminates the necessity of hauling it by team across country, which is a hazardous operation especially in seasons when the roads are rough.

Fig. 59—LOADING A SHELL WITH SOLIDIFIED NITROGLYCERIN

When loading, the sticks of solidified nitroglycerin are broken by hand and packed into the shell by the aid of a wooden stick. See figures number 58 and 59.

In shooting, the shells must be placed in the hole one above the other, that is, with no anchorage in between, otherwise the entire shot might not explode.

After the loaded shells are placed in the hole, the firing is done by dropping a "jack squib" with a lighted fuse attached to the percussion cap in the interior of the squib. The "jack squib" is filled with solidified nitroglycerin.

Fig. 60

Torpedo—This consists of a tin shell or tube a few inches in diameter according to the size of the well to be shot and in lengths of from two to ten feet. The end of the shell carries a small tin tube soldered on to the point to fit over the top of the anchorage or shell below. The top shell carries a firing head under which is placed a percussion cap. The flat round plate on top of the firing head prevents the go-devil from passing by without firing the percussion cap. This flat plate is quite necessary where there is plenty of water in the hole which would greatly decrease the speed and force of the go-devil in its downward course.

Table No. 36—Capacities of Solidified Nitroglycerin Shells

Diameter	Explosive Column	Length of Shell
2 in.	30 ft. 10.8 in.	30 ft. 10.8 in.
2½ "	19 " 9.1 "	19 " 9.1 "
3 "	13 " 9.6 "	13 " 9.6 "
3¼ "	11 " 9.6 "	11 " 9.6 "
3½ "	10 " 2.7 "	10 " 2.7 "
3¾ "	8 " 11.4 "	8 " 11.4 "
4 "	7 " 11.0 "	7 " 11.0 "
4¼ "	7 " 0.9 "	7 " 0.9 "
4½ "	6 " 4.4 "	6 " 4.4 "
4¾ "	5 " 9.2 "	5 " 9.2 "
4⅞ "	5 " 6.1 "	5 " 6.1 "
5 "	5 " 3.1 "	5 " 3.1 "
5¼ "	4 " 9.9 "	4 " 9.9 "
5½ "	4 " 5.5 "	4 " 5.5 "
5¾ "	4 " 1.7 "	4 " 1.7 "
6 "	3 " 10.3 "	3 " 10.3 "
6¼ "	3 " 7.2 "	3 " 7.2 "
6½ "	3 " 4.7 "	3 " 4.7 "
6¾ "	3 " 2.5 "	3 " 2.5 "
7 "	3 " 0.4 "	3 " 0.4 "
7¼ "	2 " 10.6 "	2 " 10.6 "
7½ "	2 " 9.1 "	2 " 9.1 "
7¾ "	2 " 7.7 "	2 " 7.7 "
8 "	2 " 6.4 "	2 " 6.4 "
8¼ "	2 " 5.2 "	2 " 5.2 "
8½ "	2 " 4.2 "	2 " 4.2 "
8¾ "	2 " 3.4 "	2 " 3.4 "
9 "	2 " 2.6 "	2 " 2.6 "

Table No. 37—Capacities of Liquid Nitroglycerin Shells

Diameter	Explosive Column	Length of Shell
2 in.	30 ft. 8.1 in.	30 ft. 10.8 in.
2½ "	19 " 6.0 "	19 " 9.1 "
3 "	13 " 6.0 "	13 " 9.6 "
3¼ "	11 " 5.8 "	11 " 9.6 "
3½ "	9 " 10.7 "	10 " 2.7 "
3¾ "	8 " 7.2 "	8 " 11.4 "
4 "	7 " 6.6 "	7 " 11.0 "
4¼ "	6 " 8.2 "	7 " 0.9 "
4½ "	5 " 11.5 "	6 " 4.4 "
4¾ "	5 " 4.1 "	5 " 9.2 "
4⅞ "	5 " 0.9 "	5 " 6.1 "
5 "	4 " 9.8 "	5 " 3.1 "
5¼ "	4 " 4.4 "	4 " 9.9 "
5½ "	3 " 11.8 "	4 " 5.5 "
5¾ "	3 " 7.7 "	4 " 1.7 "
6 "	3 " 4.1 "	3 " 10.3 "
6¼ "	3 " 0.8 "	3 " 7.2 "
6½ "	2 " 10.1 "	3 " 4.7 "
6¾ "	2 " 7.7 "	3 " 2.5 "
7 "	2 " 5.4 "	3 " 0.4 "
7¼ "	2 " 3.4 "	2 " 10.6 "
7½ "	2 " 1.6 "	2 " 9.1 "
7¾ "	2 " 0.0 "	2 " 7.7 "
8 "	1 " 10.5 "	2 " 6.4 "
8¼ "	1 " 9.1 "	2 " 5.2 "
8½ "	1 " 7.9 "	2 " 4.2 "
8¾ "	1 " 6.8 "	2 " 3.4 "
9 "	1 " 5.8 "	2 " 2.6 "

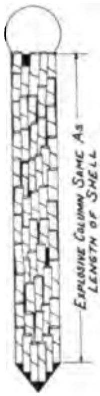


Fig. 61—A SHELL LOADED WITH SOLIDIFIED NITROGLYCERIN

Fig. 62—A SHELL LOADED WITH LIQUID NITROGLYCERIN

To find sand length of a shell or shells look at the above illustrations, then refer to the table on page 221 under length of shell, and multiply length given by the number of shells to be used.

Shell Anchor—Figure 63 shows the anchorage used below the filled shells of nitroglycerin or solidified nitroglycerin. It consists of a tin tube of about two inches in diameter with a pointed end at the bottom and the top end made to fit over a tube of like diameter at the bottom, of the bottom shell.

Fig 63

Fig 64

Go-Devil—This consists of a three edged elongated piece of cast iron, pointed at one end. It weighs about twenty pounds and is made of cast iron so that it will be entirely broken up at the instant of exploding the shot and not come out of the hole in large pieces or clog in the hole.

After placing the loaded shells in the hole at the proper place the go-devil is dropped in the well and on striking the firing head explodes the shot.

Fig. 65—A WELL STARTING TO FLOW OIL

Jack Squib—This is used to explode the shot in the hole. It consists of a small tin tube pointed at one end and an inner tube partially filled with solidified nitroglycerin or dynamite with a fuse wound around the outside of inner tube. A pocket for the percussion cap is put on the outside of the inner tube at the point to where it is filled with the explosive.

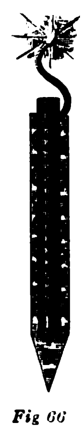


Fig 66

The heat of the burning fuse on the outside of the inner tube would possibly fire any explosive opposite it. The space between the inner and outer tubes is filled with sand. Usually the explosive fills only one-third of the bottom of the inner tube. Before dropping in the hole the end of the fuse is lighted. The fuse is long enough so that the squib will not explode before reaching the position of the loaded shells in the hole. It is used in firing solidified nitroglycerin shots.

Cleaning Out—After shooting and before cleaning out, the well should be allowed to stand over night to allow for the caving in of the sand loosened by the shot. The well should be thoroughly cleaned out until the steel measuring line can be run to the full depth of the well prior to the shot.

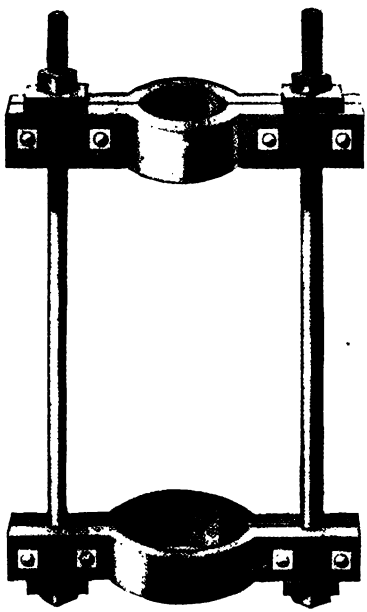


Fig. 67—ANCHOR RODS OR CLAMP

Used in anchoring the tubing to the casing or drive pipe. This, with the assistance of the weight of the tubing in the well, keeps the gas under control, and in addition, expands the rubber packer, thereby preventing the leakage of gas around it from the portion of the well below the packer.

Tubing and Packer—The gas conductor or tubing of a gas well is made of extra heavy pipe of from two to four inches in diameter, the size being selected according to the flow of the well. Some gas men believe that it is policy to use as small a tubing down to 2-inch, as is possible, even though it be necessary to "pull in" the first few joints when starting to tube the well. The idea of this is that it is easier to get water out of the well and, not being able to drain the well as quickly of the gas, the life of the well would be longer.

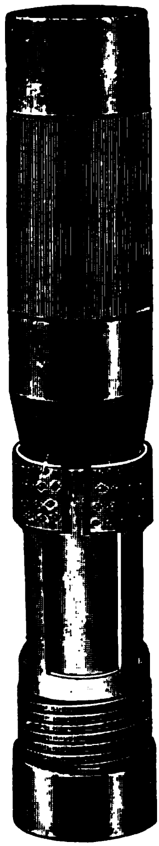


Fig. 68—DISC WALL PACKER

A packer consists of a steel plunger with a rubber ring fitting close to the walls of the well, the rubber being ten to twenty inches in length. An anchor packer has the tubing connection or thread on the top and bottom, while the disc wall packer has tubing connection on top only, the rubber being supplemented with a set of jaws working over a cone and held in place by a spring and a cast iron disc. If the packer is an anchor packer, it is placed a few joints off the bottom of the tubing and is anchored in place, after the tubing rests on the bottom of the well, by the weight of the tubing on top of the packer with the assistance of anchor irons and rods pulling the tubing downward on the surface. The amount of tubing underneath the packer is dependent upon the height of the sand above the bottom of

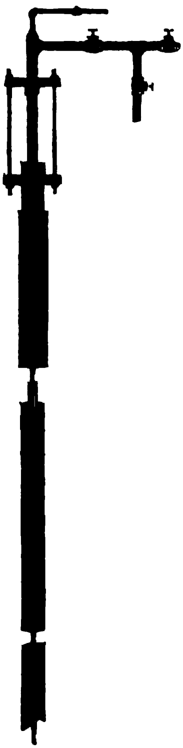


Fig. 69—Sectional View of Gas Well with 2-in. Tubing and ¾-in. Water Siphon.

the well and the location of the hard strata in which it is desired to set the packer above the gas sand. The joint of tubing which would come opposite the gas sand is perforated with ¼-inch holes drilled through the pipe the full length of the joint, with about a foot space between perforations.

The disc wall packer is set on the bottom of the first joint of tubing that is let into the well. When the packer reaches the proper distance or opposite the location desired to set the packer, a short piece of pipe—¾-inch pipe preferred—is dropped through the tubing. This breaks the disc in the packer, thereby releasing the spring and jaws, after which the packer will support the tubing without use of elevators and the tubing can be anchored down on the surface without liability of packer dropping. The disc wall packer can be pulled out of the well and a new disc inserted in the packer if it is desired to lower the packer below its first location or to use the packer again in another well.

It is a good idea to use a three-foot nipple and collar just above the packer in the string of tubing with a right and left-hand thread, so if at any time in the future it is desired to pull the tubing and the packer has become stuck, the whole string of tubing can be turned at the left-hand thread and pulled.

In event of the packer leaking after being anchored and the well is shut in, blow off well and put in one-half bushel of wheat and four or five pounds of shot on top of the wheat. The shot will weigh down the wheat and assist in making the

packer tight. If there is no water on top of the packer, put in two or three barrels of water. After being allowed to stand two or three hours, the well can be shut in to determine the effectiveness of the operation.

All tubing should be painted before placing in the well, not forgetting tong marks after it is set up.

In wells of 10,000,000 cubic feet daily capacity and larger, where a long string of casing has been used and the pressure does not exceed 300 pounds to the square inch, the casing itself may be used as tubing.

Fig. 70—CIMARRON RIVER FIELD

When a gas well is overhauled (*i. e.*, the casing, tubing, and water pipe are pulled and renewed), it is a good policy to test the well before and after the work.

Often an old gas well, whose flow and rock pressure have dropped, can be shot to advantage. This requires the pulling of the tubing and water pipe prior to shooting.

It is advisable to shoot the well with at least 100 feet of water on top of the shot. Dry shooting is less effective on the sand though more spectacular.

THE USE OF CASING FOR TUBING

There are a few gas companies throughout the country that make a practice of using casing for tubing. No doubt it is somewhat cheaper than putting in a line of tubing with a packer. In some cases no packer is used and the casing setting on a rim of rock is depended upon to make a tight joint or seat. This can not be considered a safe method to pursue. If the gas should start to leak under the bottom of the casing it might eventually become a "wild well" especially in the Gulf Coast country where the formations are soft. A "wild well" means a great waste of gas even though it may be eventually controlled.

The only practical method to pursue is to tube the well with standard tubing and set the packer opposite a hard formation just above the gas sand. If this method is used throughout a gas field it will certainly lengthen the life of it.

There is considerable difference between the weight of casing and tubing of the same size. The following table is given as an illustration:—

Diameter in inches	Weight Per Foot In Pounds	
	Tubing	Casing
2	4.00	2.16
3	7.54	3.96
4	10.66	5.85
6	18.76	.....
6.25	.....	11.50

From the foregoing comparisons the difference between the weight of casing and tubing can readily be noted. Casing was never designed to act as tubing. It was designed to stand external pressure, while tubing was designed to hold internal pressure. Naturally there would be some difference in the weight and also the cost per foot.

Casing is more liable to leak at the joints than tubing. After a string of tubing with a packer has been set in a well it should be left shut in for twenty-four hours and then ex-

amined for leaks. Should the tubing show a leak the gas should be blown off then the anchor rods can be tightened and an additional test made.

This is one great advantage over casing which is not anchored by rods and clamps. The weight of the casing is depended upon to hold it tight on the rim of rock upon which it is set. If it should show a leak there is no way to clamp it down tighter.

TABLE No. 38—TUBING

Nominal Inside Diameter Inches	Thickness Inch	Nominal Weight per Foot Pounds	Number of Threads per Inch	Outside Diameter of Couplings Inches
1	.134	1.67	11½	1.687
1¼	.140	2.24	11½	2.062
1½	.145	2.68	11½	2.375
2	.154	4.00	11½	2.937
2 patent	.174	4.50	11½	2.937
2½	.204	5.74	11½	3.500
3	.217	7.54	11½	4.062
3½	.226	9.90	11½ and 8	4.687
4	.237	10.66	10 and 8	5.187
6	.280	18.76	8	7.343

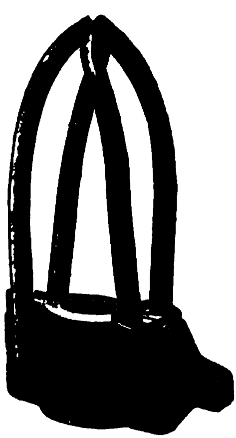


Fig. 71—ELEVATORS

Elevators—These are used for letting in and pulling out drive pipe, casing, tubing, and water pipe. The size shown in Fig. 71 is for 2-inch tubing. In using elevators always see that both elevator links are caught in the tackle block hook.

Dry Holes—In the event of drilling a dry hole and striking the gas or oil sand, it is very essential to plug the hole just above the sand with either a rubber or wooden plug. If wood is used, dry pine is the best, as it will swell soon after being immersed in the water in the bottom of the hole and make a perfectly tight fit.

Fig. 72—WOOD DRY HOLE PLUGS

Well Connections—After a new gas well has been shut in and anchored it should be blown off a day or two later and the anchor rods re-tightened. In connecting up a "tubing blow-off" on a gas well, the blow-off should point at right angles from the tubing with no angles between the blow-off opening and the tubing. Otherwise the reaction of the gas issuing from the blow-off will tend to force the blow-off connection around and may result in a serious accident.

Water Propositions—With gas wells of medium size making water, use a ¾-inch "siphon" or water line hanging from the top inside of the tubing and with a "blow-off" on the top end. The bottom of the "siphon" should be plugged and hung one foot from the bottom of the well. Perforate the joint of the pipe opposite the main gas sand with ¼-inch holes, drill through both sides of the pipe and space one foot apart. If blown often, this method keeps the water out of the well.


Fig. 73—LIMIT PLUG. for plugging abandoned gas or oil wells and for shutting off flows of water.

Where there is no "floating sand" in the well, the same method can be installed with 1-inch working barrel and anchorage on bottom of ¾-inch, using the ¾-inch as a sucker rod as well as a conductor for the water. The top of the ¾-inch should work through a stuff-

ing box on the top of the tubing with a small walking beam and gearing, using a horse for power, or a two to four h. p. gas engine.

In equipping gas wells with ¾-inch water pumping outfits where the size of tubing is over 3-inch, a cast iron

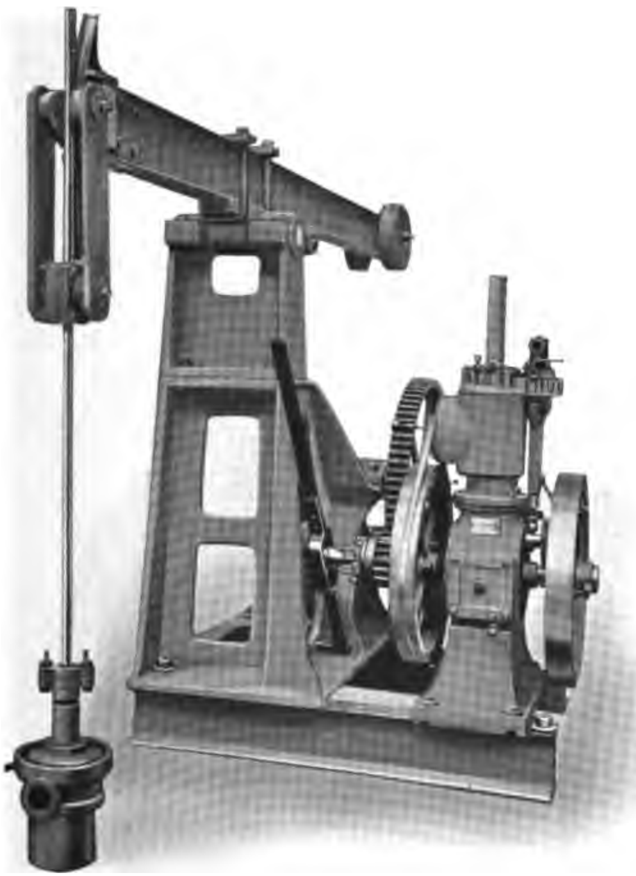


Fig. 74—PUMPING POWER FOR PUMPING OIL WELLS OR WATER FROM GAS WELLS

spider can be used on every second or third joint. The spider fits loosely in the tubing and is made to slip over the ¾-inch, but not large enough to slip by a ¾-inch collar. This method prevents the ¾-inch from weaving while pumping.

There are specially made gas pumps which can be used in connection with this ¾-inch without wasting any gas.

With the blowing out method, water can be raised through a ¾-inch "siphon" from a depth of 1200 feet with a 75-pound gas pressure, and from a depth of 1500 feet with a 125-pound gas pressure.

Cement, when properly mixed and hydrated before it goes into the well, will set in a mineral water.

A small gas well cannot be properly "blown off" and cleaned of water where casing is used in place of tubing.

Pumping Powers—The pumping power is adapted for pumping small oil wells in isolated localities. It is also used extensively for pumping water from gas wells down to a depth of 3,500 feet by using the ¾-inch water line for both tubing and sucker rods. With a friction drum attached to the power, it is possible to pull the tubing and sucker rods from wells 2,600 feet in depth. With a larger pulley on the engine shaft, which will increase the speed, the drum may also be used for bailing.

Fig. 75—PUMPING HEAD

Pumping Heads—Pumping heads are clamped to the tubing and are used for pumping water from gas wells, using either gas, air or steam under pressure for power. The water is pumped through a ¾-inch line same

Fig. 76—A GAS WELL IN MONROE (LA). FIELD

as with a pumping power. The heads for steam are 12 inches in diameter, 34 inches long, with a 30-inch stroke; for air and gas they are 12 inches in diameter, 36 inches long, with a 32-inch stroke.

Heads can be operated on pressures ranging from 40 lb. to 400 lb., and will pump wells any depth down to 2600 feet.

Capping—This operation merely consists of placing a gate on the tubing or casing and "shutting in" the well.

If, in drilling a gas well, a volume greater than 35,000,000 cubic feet daily capacity is anticipated, and the conditions of the well are favorable for casing to be used in place of tubing, screw a gate on the casing and reduce the size of the drill or bit just before drilling into the gas vein. If reducing the size of the bit is objectional, use a swedge nipple and a gate one size larger than the casing.

Gas Well Drip—A gas well should not be connected without using a drip near the well, whether the gas be absolutely dry or not.

This drip should be placed from three to four joints of pipe distant from the well. The length of the lead and tail of the drip is dependent entirely upon the amount of water in the well. For a 2-inch or 3-inch lead line use 6-inch pipe in the drip. For a 4-inch lead line use 8-inch pipe in the drip, and for a 6-inch lead line use 10-inch pipe in the drip. A stop cock should never be used on the blow-off of the drip.

This type of drip should be set with the intake slightly higher than the T in the vertical line, likewise the tail of the drip should have the intake into the tail higher than the blow-off so it can be more easily drained.

Gas Well Lead Lines—A gas well lead line is a pipe line connecting the well with the main line. Where there is liability of the pressure in the field line or main line exceeding

Fig. 77 —Gas Pump for Pumping Water from Gas Well through ¾-inch Pipe, using the ¾-inch as a Sucker Rod and Tubing for Water Discharge Combined.

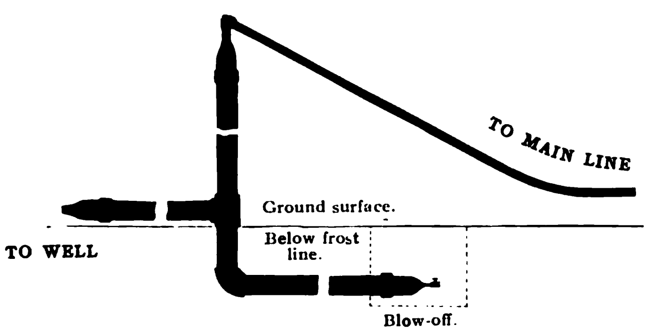


Fig. 78—GAS WELL DRIP

the pressure on the gas well, a check valve should be placed on the lead line. Stopcocks should not be used on gas well lead lines.

Care of Gas Wells—After a gas well has been completed and it is desired to move the derrick, a "three-pole derrick" or "gin poles" can be erected, or a single mast or gin pole can be used in case of emergency, for pulling tubing or water pipe.

The common method of expelling water from the well by blowing the gas into the atmosphere is an extravagant waste of gas. Wherever it is possible, the ¾-inch siphon water line with pump attachment should be used.

A gas well cannot be blown off and cleared of water where casing is used in place of tubing.

Fig. 79—GAS WELL DRIP

Fig. 80—Walking Beam Method of Pumping Water from a Gas Well. Power is furnished by a 3 h. p. gas engine and the water is pumped through the ¾-inch siphon. The ¾-inch pipe is used as a sucker rod and tubing.

In the event of a gas well constructed with a ¾-inch siphon becoming flooded, the siphon can be pulled a few joints and the well shut in; then, after an accumulation of pressure, an attempt can be made to raise the water. If the ¾-inch pipe, when opened, does not make a showing of water, it should be pulled one or two joints more and the process repeated until the level of the water in the well is determined. After each attempt to raise the water, the well should be capped and allowed to stand long enough to permit the gas pressure to raise to at least 50 lb. After the well begins to throw water and the water level is lowered to the bottom of the ¾-inch pipe, the pipe should be lowered half a joint and the operation repeated until the full length of the ¾-inch pipe is back in the well. This method will often save the expense of erecting a derrick and bailing.

When a gas sand becomes coated with paraffine or salt the only sure method of cleaning out the well is by the "steaming process." This merely consists of turning live steam, at about 125 lb. pressure, into the ¾-inch siphon and up through the tubing into the atmosphere. The boiler should be placed on the windward side and about two hundred feet from the well.

It is policy to "blow-off" gas wells of medium size, especially those making water, in summer as well as in winter, even though the well be closed in, except where pumping apparatus has been installed to free the well of water. It is not necessary to blow a well as often in summer when the well is shut in as it is in the winter or when feeding into the line.

In the event of a leak developing in the tubing of a gas well, the tubing should be pulled and tested under pressure on the ground.

Salt Water Propositions—Where gas wells are troubled with salt, which frequently clogs the tubing to such an extent that gas cannot pass through it, it becomes necessary to

dissolve the salt, which is done by pouring water down the well. To admit fresh water, a "swaged water jug" which is made of a piece of 6⅝-inch casing about three feet long, swaged at both ends to two inches, is used. This is screwed into the top of the tubing, and holds about four and one half gallons of water.

A bailing machine is then placed in position to agitate the fresh water in the tubing in order to dissolve the salt and bail it from the well.

Fig. 81—PULLING TUBING WITH A TRACTOR

It often happens that ten or fifteen joints of tubing, aggregating 200 to 300 feet, will fill up solid with salt.

When fresh water fails to dissolve the salt, it becomes necessary to pull the tubing and to "shoot" the well; that is the sand at the bottom of the hole. Usually from 20 to 60

quarts of nitroglycerin are used, depending upon the thickness of the sand.

The well is then cleaned, re-tubed and treated with fresh water. From 30 to 100 gallons of fresh water is considered a "dose" and is allowed to remain from twenty to twenty-four hours on the salt before blowing out. This has the effect of dissolving the salt and washing the gas sand. It requires extreme care in handling to prevent the well clogging and being ruined.

In certain localities where the gas is found in the Clinton sand it is found necessary to "water" a well twice weekly, and then it is only possible to keep them in commission about half the time, while others only require attention once or twice a month.

The Clinton Sand, which extends from Hocking County on the south to Lake Erie on the north, is not only one of the most prolific gas sands ever developed, but probably contains more salt than any other field. This field is different from many others in that it contains but one paying gas formation.

Use of Abandoned Gas Wells—Many times gas wells are abandoned even though they can supply enough gas for a few consumers. It is often profitable for land owners, where gas wells are abandoned on their property, to purchase from the gas company abandoning the well the drive pipe casing, and tubing, in order that it may be left in the well, thereby furnishing enough gas for one or more consumers.

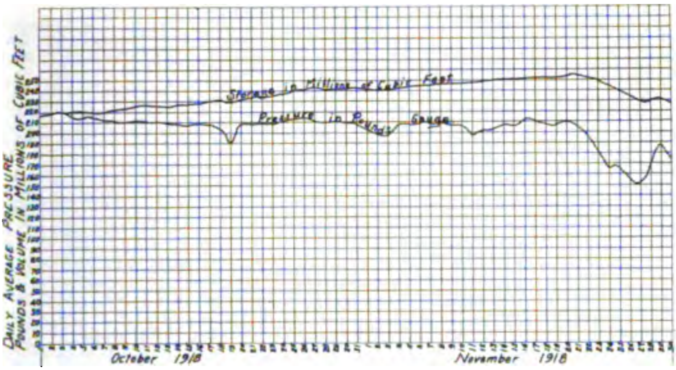
Sometimes after wells are abandoned and become filled with water, gas continues to bubble through the water. To save this, construct a large galvanized iron drum and place over the well. The drum should be set in a water filled pit surrounding the well with guide posts, the same as a gas holder, to allow the drum or tank to raise with increasing volume of gas. Connection can be made with top of the drum by a one-inch rubber hose to an iron pipe leading to

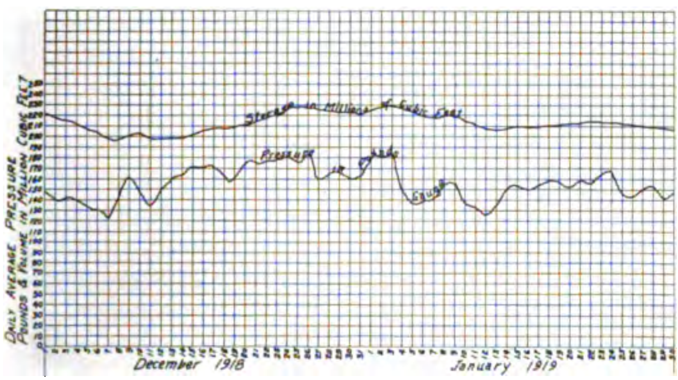
the consumer's house. This method will always insure a low pressure, as too much pressure will cause the drum to raise until the gas breaks the water seal and escapes into the atmosphere. To increase the pressure, place a weight on top of the drum. It must be borne in mind that while the leaking gas from an abandoned well might not run a stove or furnish enough gas for one consumer continuously, the gas could be collected in the drum during the twenty-four hours in sufficient amount for occasional use.

STORAGE OF NATURAL GAS IN THE GAS SAND

One of the large gas companies in the east has been using one of its small gas fields for the past few years for the storage of natural gas. It has appealed to the author that the advantages found in this particular work are of exceptional interest to the gas fraternity. From the geological point of view it also is of unusual interest. In this article there are described three fields within a distance of a few miles of one another. In this locality there are found two productive gas horizons. The shallower sand is found at a depth of from 1500 to 1850 feet and the deeper from 2400 to 3000 feet below the surface. In Fig. number 83 the relative location of the fields is shown,

In Field "A", which might be termed the storage field, there have been drilled 35 wells to the shallower sand at an average depth of about 1850 feet. However, only 15 of the 35 proved productive and three of the 15 have since been abandoned. Gas has been used from this field since the early 90's. The original rock pressure of about 600 pounds became so exhausted by the summer of 1914 that the wells were unable to deliver much gas into the Company's main transmission lines, in which, at this point, there must be maintained a pressure of about 90 pounds in order to give good service at the principal market, 26 miles away. A compressor


Daily Average Pressure
Pounds & Volume in Millions of Cubic Feet
Storage in Millions of Cubic Feet
Pressure in Pounds Gauge
October 1918
November 1918


Daily Average Pressure
Pounds & Volume in Million Cubic Feet
Storage in Millions of Cubic Feet
Pressure in Pounds Gauge
December 1918
January 1919

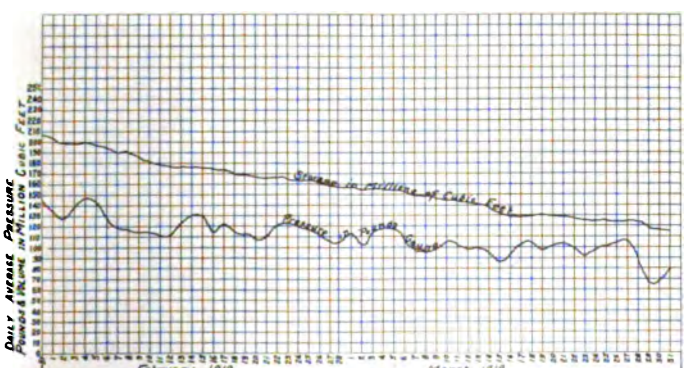

Daily Average Pressure
Pounds & Volume in Million Cubic Feet
Storage in Millions of Cubic Feet
Pressure in Pounds Gauge
February 1919
March 1919

Fig. 82

station was then erected, having a rated capacity of ten million cubic feet per day.

Meanwhile, two new gas fields had been discovered and partially developed, one (Field B), about 3 miles from Field A and the other (Field C) about 7 miles from Field A.

Field B produced gas from the deeper sand and the wells had an average initial closed rock pressure of about 800 pounds. Field C had some wells producing from the shallower sand which had an average initial closed rock pressure of about 550 pounds and some producing from the deeper sand, which, in this field, had an average initial closed rock pressure of about 750 pounds. The gathering lines from these three fields are connected to one of four main transmission lines. These four main transmissions are connected by by-pass lines so that the gas can be turned into any one of the main lines as desired.

Marketing conditions with this Company were such that it was very desirable to use these fields as a reserve for the heavy peak loads during the winter months. The old Field A was being rapidly exhausted under the pull of the compressors, and its production soon fell below their capacity.

In order to increase the maximum delivery capacity of the system and to save the old field, the experiment was made to turn gas from the high pressure wells in the newer fields into the wells of the old field. During the first summer, about forty-five million cubic feet of gas was placed in storage. The records of the pressure gauge and of the orifice meter for the following winter showed that the experiment was a success. The amount placed in storage has been gradually increased each year and it has proved to be a great help, not only by increasing the maximum delivery capacity of the system, but by greatly aiding in the regulation and operation during the peak load periods.

For example, note how the storage field is used, during a typical winter day with its attendant sudden changes in

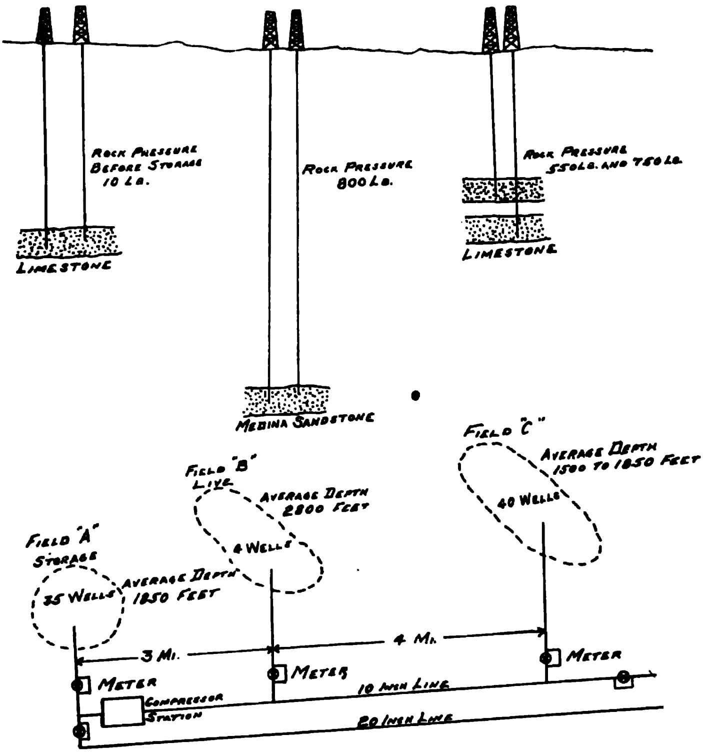

Rock Pressure Before Storage 10 Lb.
Limestone
Rock Pressure 800 Lb.
Medina Sandstone
Rock Pressure 550 Lb. and 750 Lb.
Limestone
Field "C"
Average Depth 1500 to 1850 Feet
40 Wells
Field "B" Live
Average Depth 2800 Feet
4 Wells
Field "A" Storage
35 Wells
Average Depth 1850 Feet
3 Mi.
4 Mi.
Meter
Meter
Meter
Compressor Station
10 Inch Line
20 Inch Line

Fig. 83

temperature, by the Company which has a large domestic heating load. Suppose, as is often the case, a sudden drop in temperature, during the night has prevented the building up of a very high line pressure for the early morning pull. The storage field is ordered turned on, say, at 7 A. M. and the field men are started out with orders to turn on all reserve wells. It is perhaps two hours before the reserve wells are all feeding, but the storage is turned on by the opening of a single gate. After the noon hour, the demand decreases so the storage field can be closed, say at two o'clock, and allowed to remain so until the evening pull and is again ordered on at about 5 P. M. About 8 P. M. the storage field is ordered closed. Later the line pressure builds up, necessitating the shutting off of the gas from the reserve wells, but instead of sending men out at night to close the well gates by the operating of three or four main line gates, the gas from the reserve fields is shut off from the city and is turned into the storage field. The next morning, when the breakfast pull is on, they are switched from the storage back into the city if needed, or, if the weather has moderated sufficiently, the wells may be shut in.

The gas produced in Fields B and C is measured separately by orifice meters, and likewise, the gas passing in and out of the storage field. The meter on the storage field has a five inch orifice and the gauge lines are so connected that when the direction of the flow is changed it is only necessary to close two small valves and open two small valves to reverse the orifice meter.

The average daily delivery capacity of the storage field is about ten million cubic feet with a shut-in pressure of about 175 pounds in the field and delivering into the main transmission lines at a pressure of 90 pounds.

The storage of gas in any abandoned or exhausted gas sand is not possible. In some sands the gas would rapidly be dissipated and the sand could not be used at all for storage

purposes. There are a few fields, no doubt, throughout the country in which this idea could be carried out successfully. The one method to pursue is to experiment to determine the possibilities of this nature by turning gas into the wells and allowing them to remain shut in for a reasonable period and watch the results, then the gas should be drawn out of the field and pressures taken. From these experiments one can determine whether or not the field is capable of being used as a storage field.

An interesting feature regarding the storage of gas has been the pressure. During mild weather as gas is being fed into the field the pressure gradually is built up, but when the field is afterwards shut in the pressure gradually settles as apparently the stored gas finds its way to the further recesses of this particular horizon. When this reservoir is drawn upon for reserve during stresses of severe weather, the converse happens. If the field is steadily drawn upon for a time there is a marked decline in pressure, but again shut it in for say twenty-four hours and the pressure is again built up to perhaps very nearly what it was previously.

NATURAL GAS STORAGE

By L. S. Panyity,* Columbus, Ohio

(New York Meeting, February, 1919)

"The question of natural gas supply is receiving careful consideration in many parts of the country, as in the winter months it is quite a problem to have on hand sufficient gas to satisfy the demand. Increasing the output of wells by the application of vacuum has been tried with various results and large companies have attempted to keep up the supply with gas compressors. The possibility of storing natural gas in the sands of exhausted gas pools has been tried in a few instances with satisfactory results. This method may prove of practical value in solving the problem, especially in the

*Geologist, Ohio Fuel Supply Co.

case of towns that formerly obtained gas from their immediate vicinity, but now must search for new pools.

In all cases, only part of the available supply is utilized during the warm weather, so that many wells are shut-in, yet during the winter months, the supply is not sufficient even with all the wells on the line; in such cases it would be of great value if a large volume of stored gas were on hand, obtained through wells that would have been standing idle during the summer.

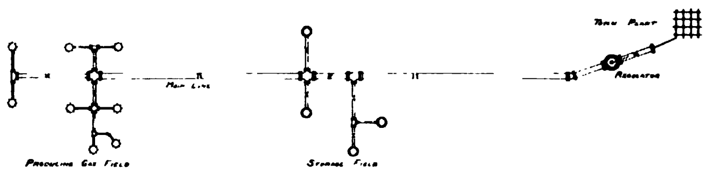


Fig. 84

Idle producing wells having considerable "rock pressure", will force gas into the exhausted, or storage wells, and this gas will be used only when the regular supply falls short (Fig. 84). If two gas wells of different pressures are connected, the one having the greater pressure will feed the other, until the pressures are at an equilibrium. The same results will be obtained if an exhausted gas well is connected to a high-pressure gas line. High-pressure lines equipped with regulators near the town plant have considerable pressure, so that storage wells connected to such a line will receive gas from the line as long as the line pressure is greater than the well pressure. During a period of heavy consumption of gas, the pressure on the main line is greatly reduced, so that gas from the storage wells will flow into the lines. An arrangement of this kind will work automatically, the flow of gas into or from the storage wells depending on the pressure carried in the line.

It is advisable in most instances that the flow into and from the storage wells be regulated by means of gates, instead

of automatically. In addition, the volume of gas should be metered as it is forced into or passes from the wells; the pressure also should be noted. By properly charting the meter and pressure records, the characteristics of the individual wells may be determined.

The geological conditions existing in the storage field, as well as in the producing field, must be taken into consideration. Best results are obtained where the storage reservoir is in a shallow sand and the producing horizon is deeper, so that the producing sand will have a higher pressure. This will have a tendency to reestablish the original rock pressure in the artificial reservoir. It is unlikely that a rock pressure greater than that which existed originally can be obtained. A lenticular-shaped sand body is preferable, as a good control over the entire reservoir is necessary. The location of all wells that have been drilled must be known and put in such a condition that they may be used; if this is not possible the wells must be properly plugged.

In some instances the sand used for storage may make large quantities of water, a difficulty that may be overcome by pumping. Best results are obtained by drilling a pocket below the sand in which the water may accumulate and from which it may be pumped through the working barrel, in the same way as it is customary to pump oil; the storage and recovery of the gas being through the casing head.

This storage method may be used to advantage in many towns; for instance, Tiffin, Ohio, formerly the center of a large gas-producing area, but now dependent on outside sources, which in times of great demand are not sufficient for the needs of the town. It may be possible to find nearby an exhausted gas pool in such condition that this method may be tried. The system allows considerable latitude and may be installed to suit the requirements of the particular case."

DISCUSSION BY I. N. KNAPP—"The possibility of storing natural gas in the sands of exhausted gas pools, as set forth

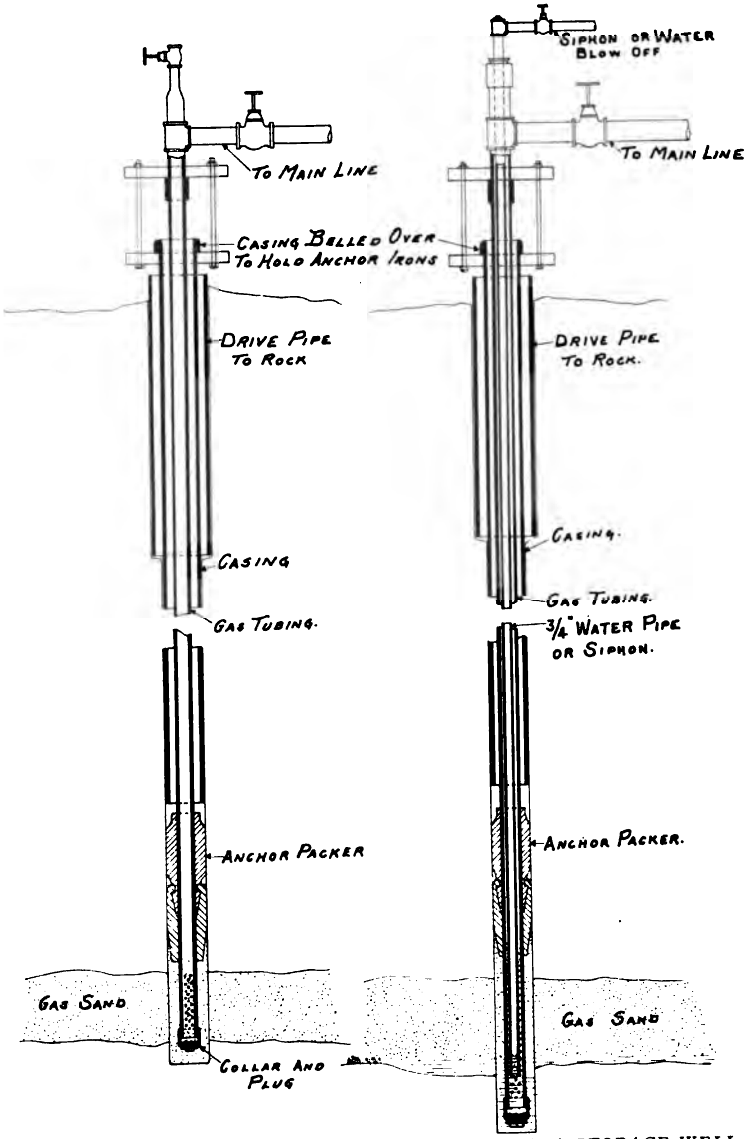


Fig. 85—A DRAWING OF A PRODUCING WELL AND A STORAGE WELL

in Mr. Panyity's paper might be, in many cases, a good engineering proposition, but it cannot be considered as a practical business proposition under the usual competitive leasing and operating conditions that have thus far existed in the natural gas business. Under the usual conditions of diversified land ownership and leasing with all lack of co-operation, various operators drill into the same pool or reservoir and thus drain out the gas from under each others land. To attempt to use the depleted sands of any one pool for storage purposes having such various competing ownerships would be highly impractical considered from operating and business standpoints unless there was co-operation with other interests owning adjacent wells and leases or the purchase of the same.

Also it would be very difficult to find out whether all old or abandoned wells in any pool had been properly plugged in a manner that would certainly be effective and prevent all waste of gas brought from a distance for such underground storage. Another operating condition against Mr. Panyity's proposition is the probability that no lease ever made in the past contemplated the use of a gas sand for storage purposes. Very likely then, one might find that he had a lawsuit on hand for unlawful use of a lease if he attempted the storage of such gas without first obtaining additional lease rights.

In some instances salt water could not be pumped from a gas well in the customary way of pumping oil wells on account of the deposition of salt in the pump valves or in the working barrel or tubing. Very ingenious compressed air jets have been devised and arranged with suitable piping to blow out such salt water accumulations. In many pools it would be impracticable to drill a water pocket below a gas sand, as suggested, since such deeper drilling would probably intensify water troubles.

I know it is perfectly practical to compress air and use a depleted gas sand for storing the air from the actual use of

such a method covering a period of seven years. In this case the compressed air was distributed by pipe lines for use in field pumps for gathering oil and in blowing oil out of wells instead of producing by the usual oil pumping methods. The wells were about 720 feet in depth. With this storage in operation many times the capacity of the air compressor could be used for short intervals without any appreciable loss of air pressure, and also when there was no air being used there was no appreciable gain in pressure during such intervals. Two two-stage compressors were used with approximately 200 H. P. of gas engine capacity: we ran 24 hours per day. I do not remember the compressor capacity in cubic feet of free air.

The original rock pressure of the depleted sand in question was 305 pounds and the open flow capacity of the well as a gasser was around two million cubic feet per 24 hours. When the air was attached to the well the gas had been used down to a rock pressure of 125 pounds. The production was then small and the gas was wet and troublesome to use. In the course of a few months' use of the compressors, a rock pressure of 290 pounds of air was developed and there was no water trouble at that pressure. The extent of the sand used for air storage was small, probably not over 20 or 25 acres, as shown by dry holes and exhausted wells. The thickness of the porous gas sand probably did not exceed seven feet. I imagine the occasional gas sands of this region were like isolated hillocks of sand resting on the salt water sand that underlaid the whole country. The depth to the gas sand was around 800 feet and it underlaid the oil sand.

I felt that I could do no possible damage by using this small depleted gas sand for air storage. But to avoid possible trouble I purchased the fee of 80 acres of land so as to fully cover the area used for the purpose mentioned."

PART FOUR

MEASUREMENT OF GAS WELLS

BASIS OF MEASUREMENT OF NATURAL GAS—PITOT TUBE FOR TESTING AND OPEN-FLOW TESTING OF GAS WELLS—MINUTE PRESSURE TESTING — ROCK PRESSURE — WORKING CAPACITY OF GAS WELLS.

Basis of Measurement of Natural Gas—The value of natural gas lies almost wholly in its ability to produce heat, and this is directly proportional to the weight. For example, two pounds of a given quantity of gas will produce just twice the heat that one pound will. It is not convenient, however, to deal with gas in units of weight, and hence it is the universal custom to speak of gas quantities as so many volume units, such as cubic feet or cubic meters.

Gas being an elastic fluid and having the property of entirely filling any vessel in which it may be contained, the actual weight of gas present in any given volume depends not only on the extent of that volume, but also upon the pressure and temperature of the gas. It is necessary, therefore, when speaking of any volume of gas, to have a definite understanding of the pressure and temperature under which the volume is measured.

It has long been the custom for natural gas men to consider 60 deg. fahr. as the standard temperature basis of measurement, and four ounces (=0.25 lb.) per square inch above an assumed mean atmospheric pressure of 14.4 pounds per square inch, as the standard pressure basis. These values are equivalent to 520 (=460 plus 60) degrees fahrenheit, and 14.65 (=14.40 plus 0.25) pounds per square inch above the absolute zero temperature and pressure, respectively.

Throughout all that follows in this book, unless otherwise specifically stated, it is to be understood that the above mentioned standards of measurement are to apply.

The specific gravity of gas as referred to air, and its flowing temperature, also enter into the computations in certain formulas and tables to follow, and these will always be considered equal to 0.60 specific gravity and 60 deg. fahr. (=520 degrees absolute) respectively, unless otherwise stated.

Pitot Tube for Testing the Open Flow of Gas Wells—The most accurate way of testing the flow of a gas well is by means of the Pitot Tube. This is an instrument for determining the velocity of flowing gas by means of its momentum. It usually consists of a small tube, one end bent at right angles, which is inserted in the flowing gas, just inside the pipe or tubing and between one-third and one-fourth of the pipe's diameter from the outer edge. The plane of the opening in the tube is held at right angles to the flowing gas At a convenient distance, varying from one to two feet, an inverted siphon or U-shaped gauge is attached to the other end, which is usually half filled with mercury or water. If the flow is over five pounds to the square inch a pressure gauge is required..

In small sized wells of not over four million feet, a 12-inch U gauge with water can be used. In wells from four to fifteen million feet, use mercury in a 12-inch U gauge, from fifteen to thirty-five million feet use a 50-pound spring gauge. Above thirty-five million feet use a 100-pound spring gauge. The foregoing figures are all based on a 6-inch hole.

For convenience, a scale graduated from the center in inches and tenths is attached between the two limbs of the U gauge. The distance above and below this center line at which the liquid stands in the gauge should be added, the object being to determine the exact distance between the high and the low side of the fluid in inches and tenths of inches.

The top joint of tubing or casing should be free from fittings for a distance of ten feet below the mouth of the well where the test is made. The test should not be made in a collar or gate or at the mouth of any fitting. The well should be blown off for at least three hours prior to making the test.

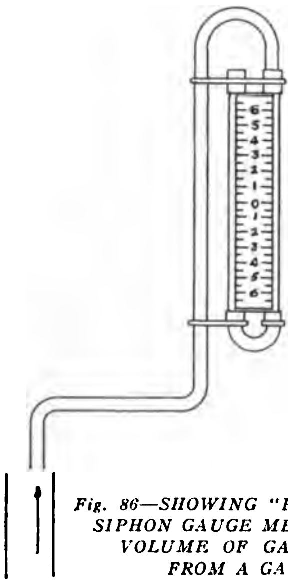


Fig. 86—SHOWING "PITOT TUBE" OR SIPHON GAUGE MEASURING THE VOLUME OF GAS FLOWING FROM A GAS WELL

Having ascertained the velocity pressure of the gas flowing from the well tubing in inches of water, inches of mercury or pounds per square inch, as outlined above, the corresponding flow is given in the following table. The quantities of gas stated in the table are based on 4-ounce pressure or 14.65 pounds per square inch absolute, 60 deg. fahr. flowing temperature, 60 deg. fahr. storage temperature, and 0.6 specific gravity (air being 1.00). If the specific gravity is other than 0.6 the flow should be multiplied by

$$\sqrt{\frac{0.6}{\text{Sp. gr. of gas.}}}$$

For flowing temperature above or below 60 deg. fahr., deduct or add 1% for each ten degrees, respectively.

Service Capacity of Gas Wells*—"When gas flows from a gas well into free air, through a wide open mouth, the discharge will be in excess of that, as it usually flows in service into a pipe line under a back pressure of several hundred pounds.

To determine the *service capacity* or amount of gas that would be given off under working conditions of being closed in and discharging gas into a pipe line, an outlet into free air should be made from the well by a branch pipe and valve. Then open this valve and also cut off the pipe line for the moment of experiment and train this branch pipe valve till the pressure of the well is up again to the working pressure of the well when in service, though now flowing into free air. Now apply the Pitot gauge as in Fig. 86, and make the measurement. The branch pipe in this experiment should be several feet in length to prevent abnormal eddyings, etc., and the same pipe would do for measuring the flow of well at all pressures.

To Determine the Daily Flow of Gas Wells—1st. To calculate the cubic feet discharged by the gas well per day from data obtained with the instrument, the fundamental formula for a weak well for velocity, in ft. per sec., is,

$$v^2 = 2gh \qquad (1)$$

where g = acceleration of gravity = $32\frac{1}{6}$ ft., and h = head or height in feet of a column of gas of unit base and of uniform density throughout equal that flowing, such as would by its weight produce the pressure causing the flow. This is analogous to the case of water flowing from an orifice.

Where water is used in the instrument as in Fig. 86, the observed head is a water column such as would produce the same flow pressure as would the gas column h of the formula,

* Courtesy of S. W. Robinson, C. E. and Oil Well Supply Co., of Pittsburgh, Pa.

as above explained. The height of one column multiplied by its density equals the same for the other, viz:

$$\delta h = \delta^1 h^1 \qquad (2)$$

$$\text{or } h \text{ (in formula)} = h^1 \frac{\delta^1}{\delta}$$

$$\text{whence } v^2 = 2gh^1 \frac{\delta^1}{\delta} \qquad (3)$$

where h^1 = head in feet of observed water column, as in Fig. 86, δ^1 = weight of a cubic foot of water, and δ = weight of a cubic foot of the flowing gas. The same is true for h^1, δ^1 in terms of mercury or kerosine, etc.

A practical formula, worked out for volume of flow of a gas well per day of twenty-four hours is, since 24 hours = 86400 seconds, $V = 86400\ av.$

$$V = 39180\ d^2 \sqrt{h}$$

where d = diameter in inches of exit orifice of gas flow, h = height in inches of the observed water column in Fig. 86, a = area of exit orifice in square feet and v = velocity in feet per sec. If mercury is used instead of water, multiply the observed height of column by the sp. gravity of mercury, 13.6, before introducing into above formula; and likewise for other liquids in the instrument.

2d. For strong wells the flow is under conditions called *adiabatic*, where the density of the flowing gas varies rapidly in passing the orifice of exit, and the formula is quiet different. See Geological Reports of Ohio, Vol. VI, and Vol. for 1890.

An exactly correct formula for this case, cu. ft. per 24 hours, is where p is absolute pressure.

$$V = 1474000\ d^2 \sqrt{\left(\frac{p^1}{14.6}\right)^{0.29} - 1}$$

But where the observed pressure is light, the following formula may be preferred:

$$V = 207000\ d^2 \sqrt{p^1 \left(1 - \frac{p^1}{41.4} + \frac{p^{12}}{1068} - \frac{p^{13}}{23170} + \frac{p^{14}}{45890} - \&c.\right)}$$

where d = diameter in inches of discharge orifice where the

Pitot tip mouth is held, and p^1 the gauge pressure observed, pounds per square inch.

This last formula may be used in all cases, and to find p^1 when h is observed for water in the glass tubes, for instance, take,

$$p^1 = \frac{h}{27.5}$$

Instead of the formulas, Table 39 will serve, from which the daily flow may be more conveniently obtained. As water, mercury, or a pressure gauge is most likely to be employed, a column of figures for each is given.

In using the table it often happens that the data come between values given in the table, when interpolation must be resorted to for close results."

Fig. 87—TAKING THE MINUTE PRESSURE TEST OF A LARGE GAS WELL

PITOT TUBE TABLE FOR TESTING OF GAS WELLS

TABLE No. 39—Discharge of Gas of 0.6 Specific Gravity from Gas Well Tubing of Different Sizes in Twenty-four Hours.

(By F. H. Oliphant)

Pressure			Discharge, Thousands of Cubic Feet			
In Inches of Water	In Inches of Mercury	In Lb. per Sq. Inch	1-inch Tubing	2-inch Tubing	3-inch Tubing	4-inch Tubing
.10			12	48	107	190
.20			17	69	154	274
.30			21	82	185	329
.40			24	94	212	376
.50			27	106	239	425
.60			29	116	262	466
.70			31	126	283	503
.80			34	134	303	538
.90			36	143	321	570
1.00			37	149	336	597
1.25			42	167	375	667
1.50			46	184	414	735
1.75	.12		50	199	447	795
2.0	.147		53	213	478	850
2.5	.184		59	238	535	950
3.0	.22	.108	65	260	586	1,041
3.5	.257	.126	70	281	632	1,124
4.0	.294	.144	75	300	676	1,202
4.5	.331	.162	80	319	717	1,275
5.0	.368	.180	84	336	756	1,344
6.	.441	.216	92	368	828	1,472
7.	.515	.252	99	397	894	1,590
8.	.588	.288	106	425	956	1,700
9.	.662	.324	113	451	1,014	1,802
10.	.736	.360	119	475	1,069	1,901
11.	.8	.396	125	501	1,126	2,003
12.	.88	.432	130	521	1,171	2,082
	1.02	.5	139	556	1,251	2,223
	1.52	.75	170	681	1,533	2,724
	2.03	1.00	197	787	1,770	3,147
	2.54	1.25	220	880	1,980	3,519
	3.05	1.5	241	963	2,166	3,852
	3.56	1.75	260	1,040	2,339	4,159
	4.07	2.00	273	1,091	2,454	4,362
	4.57	2.25	295	1,178	2,651	4,713
	5.08	2.50	311	1,243	2,797	4,972
	5.59	2.75	321	1,284	2,889	5,136
	6.10	3.00	340	1,361	3,062	5,443

PITOT TUBE TABLE—*Continued*

Pressure			Discharge, Thousands of Cubic Feet			
In Inches of Water	In Inches of Mercury	In Lb. per Sq. Inch	1-inch Tubing	2-inch Tubing	3-inch Tubing	4-inch Tubing
	6.61	3.25	354	1,416	3,187	5,666
	7.11	3.50	368	1,471	3,309	5,883
	7.62	3.75	380	1,522	3,424	6,086
	8.13	4.00	393	1,572	3,536	6,286
	8.64	4.25	405	1,620	3,645	6,480
	9.15	4.50	417	1,667	3,750	6,666
	9.65	4.75	428	1,713	3,855	6,852
	10.16	5.00	440	1,760	3,959	7,039
	12.20	6.	476	1,904	4,284	7,617
		7.	517	2,069	4,656	8,277
		8.	542	2,170	4,882	8,678
		9.	570	2,279	5,127	9,114
		10.	596	2,382	5,360	9,529
		11.	622	2,488	5,598	9,951
		12.	643	2,570	5,783	10,280
		13.	665	2,659	5,982	10,630
		14.	684	2,736	6,155	10,940
		15.	703	2,812	6,328	11,250
		16.	721	2,884	6,490	11,540
		17.	738	2,952	6,643	11,810
		18.	754	3,016	6,786	12,060
		20.	786	3,142	7,070	12,570
		22.	803	3,213	7,230	12,850
		25.	855	3,420	7,699	13,680
		30.	911	3,643	8,196	14,570
		35.	961	3,844	8,649	15,380
		40.	1,007	4,027	9,060	16,110
		45.	1,047	4,186	9,419	16,740
		50.	1,082	4,328	9,737	17,310
		60.	1,137	4,548	10,230	18,190
		75.	1,223	4,894	11,010	19,570
		90.	1,304	5,218	11,739	20,870
		100.	1,337	5,348	12,030	21,390

Multipliers for Pipe Diameters other than given in the above tables. For any different sized pipe apply the multiplier to the figures given in the above table for "one inch tubing."

1½-inch = 2.25	5 -inch = 25.0	8 -inch = 64.
2½-inch = 6.25	5⅝-inch = 31.6	8¼-inch = 68.
4¼-inch = 18.00	6 -inch = 36.0	9 -inch = 81.
4⅝-inch = 21.39	6¼-inch = 39.0	10 -inch = 100.
	6⅝-inch = 43.9	12 -inch = 144.

Minute Pressure Testing of Gas Wells—It has often been the practice to measure the capacity of natural gas wells by quickly shutting a gate or valve and noting the pressure on a gauge at the end of each minute. Usually the pressure at the end of the first minute is used to approximate the volume.

Before making this test the well should be blown off for at least three hours.

The following table gives the volume of different sized tubing in lengths of 100 feet, which is followed by a table of multipliers for different pressures to be used to obtain volume for one minute and for twenty-four hours.

VOLUME OF TUBING

TABLE No. 40

Diameter of Tubing in Inches	Volume in Cu. Ft. of 100 Feet of Tubing	Diameter of Tubing in Inches	Volume in Cu. Ft. of 100 Feet of Tubing
1	0.55	5⅝	17.26
2	2.18	6	19.63
3	4.91	6¼	21.31
3¼	5.76	6⅝	23.94
4	8.73	7¼	28.67
4¼	9.85	8	34.91
5	13.64	8¼	37.12
5 3/16	14.14	9⅝	50.53
5¼	15.03	10	54.54

The best gas well is one which, at the highest pressure, will discharge the greatest quantity of gas. The working capacity of any well can be tested by closing in the pressure by a gate at a length of half a joint or more of pipe from the open end. A gauge connected by a small pipe back of the gate will record the increased pressure. The flow can thus be measured at various back pressures by testing the open flow with a pitot tube as the pressure inside the well is increased.

TABLE No. 41

MINUTE PRESSURE OF GAS WELLS

Opposite the gauge pressure are found the multipliers for one minute and for twenty-four hours. All figures are given at 14.65 pounds, or atmospheric pressure 14.4 pounds plus .25 pounds (4 ounce basis). Specific gravity of gas 0.6. Temperature 60 deg. fahr.

Gauge Pressure	Multipliers		Gauge Pressure	Multipliers	
Pounds	For One Minute	For 24 Hours	Pounds	For One Minute	For 24 Hours
1	.051	73	80	5.443	7837
2	.119	171	90	6.126	8821
3	.187	269	100	6.808	9803
4	.255	367	110	7.491	10787
5	.324	466	120	8.174	11770
6	.392	564	130	8.856	12752
7	.460	662	140	9.539	13736
8	.529	761	150	10.221	14718
9	.597	859	160	10.904	15701
10	.665	957	170	11.587	16685
11	.733	1055	180	12.269	17677
12	.802	1154	190	12.952	18650
13	.870	1252	200	13.634	19632
14	.938	1350	210	14.317	20616
15	1.006	1448	220	15.000	21600
16	1.075	1548	230	15.682	22582
17	1.143	1645	240	16.365	23565
18	1.211	1743	250	17.047	24547
19	1.279	1841	260	17.730	25531
20	1.348	1941	270	18.412	26513
21	1.416	2039	280	19.095	27496
22	1.484	2136	290	19.778	28480
23	1.552	2234	300	20.460	29462
24	1.621	2334	310	21.143	30445
25	1.689	2432	320	21.825	31428
26	1.757	2530	330	22.508	32411
27	1.825	2628	340	23.191	33395
28	1.894	2727	350	23.873	34377
29	1.962	2825	360	24.556	35360
30	2.030	2923	370	25.238	36342
35	2.372	3415	380	25.921	37326
40	2.713	3906	390	26.604	38309
45	3.054	4397	400	27.286	39291
50	3.395	4888	410	27.969	40275
60	4.078	5872	420	28.651	41257
70	4.761	6855	430	29.334	42240

MINUTE PRESSURE OF GAS WELLS—*Continued*

Gauge Pressure	Multipliers		Gauge Pressure	Multipliers	
Pounds	For One Minute	For 24 Hours	Pounds	For One Minute	For 24 Hours
440	30.017	43224	530	36.160	52070
450	30.699	44206	540	36.843	53053
460	31.382	45190	550	37.525	54036
470	32.064	46172	560	38.208	55019
480	32.747	47155	570	38.890	56001
490	33.430	48139	580	39.573	56985
500	34.112	49121	590	40.255	57967
510	34.795	50104	600	40.938	58950
520	35.477	51086			

Example—Suppose that a well showed 320 lb. gauge pressure in one minute, and 2-inch tubing, the depth of the well being 1250 feet. From the first table the volume of 100 feet of 2-inch tubing is 2.18 cubic feet; and 1250 feet will have a volume of 12.5 times 2.18 or 27.25 cubic feet. From the second table the multiplier for one minute corresponding to the minute pressure of 320 lb. is 21.825. Hence the capacity of the well is 27.25 multiplied by 21.825, or 594.73 cubic feet per minute, 35,683 cubic feet per hour, 856,000 cubic feet per day. The daily capacity can likewise be determined directly by using the multiplier for 24 hours, corresponding to 320 lb. minute pressure, or 27.25 multiplied by 31,428 or 856,000 cubic feet per day.

If the packer is set up from the bottom, an addition will have to be made because of the additional space between the outside of the tubing and the wall of the well. Say that the packer is set up 120 feet in a hole 5⅝ inches in diameter. Then 17.26 minus 2.18 equals 15.08, the volume around the outside of the tubing per hundred feet of depth. Then the total volume around the tubing under the packer is 15.08 times 1.20, which equals 18.10 cubic feet. The volume of

the tubing is 27.25 cubic feet, as previously determined; and the total volume of the well is 18.10 plus 27.25 which equals 45.35 cubic feet. 45.35×21.825 equals 990.0 cubic feet per minute, 59,400 cubic feet per hour, 1,425,000 cubic feet per day.

Fig. 88

This method is only a comparison of the value of wells and gives results considerably under the measurement of the open flow, which is the proper method of measuring the output. Both of these methods should be accompanied by the maximum rock pressure. The best well is the one which will discharge the largest quantity of natural gas at the highest pressure.

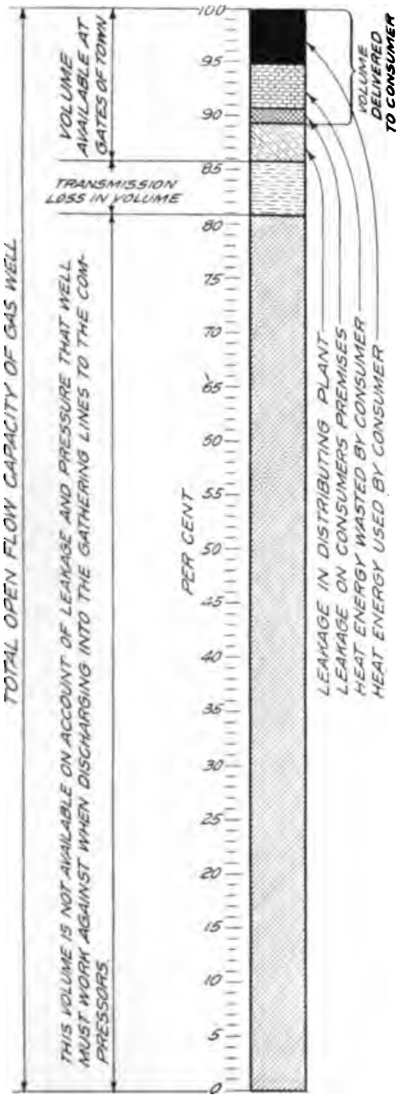


Fig. 89—PER CENT OF OPEN FLOW OF A GAS WELL CAPACITY AVAILABLE FOR DOMESTIC USE
By S. S. Wyer, in Natural Gas Service

Open Flow Capacities of Gas Wells—Unfortunately the well capacities that are generally reported by the newspapers and represented to gullible investors are the open flow capacities when the wells are discharging freely into the atmosphere. These open flow capacities are very much larger than the actual delivering capacities under routine operating conditions, as shown at the left. The data shown in this illustration were obtained by first determining the open flow capacities of representative wells and then passing the gas from these wells through meters, noting the amount that was actually delivered to the gas compressors.

It is also important to note that even after the gas reaches the consumer's premises much is lost, due to leakage and ineffective methods for utilizing the gas.

Rock Pressure—Rock pressure means the highest pressure attained in a gas well after being shut in for a period of 24 hours or longer. It is no indication of the size of the well.

The greater the rock pressure, the greater the distance the flow of a gas well can be transmitted without the assistance of a compressor.

As the gas is withdrawn from the pool, the rock pressure gradually declines until it finally becomes necessary to install compressors to raise the pressure in the lines sufficiently high to transport the gas to the market.

Working Capacity of Gas Wells Under Pressure—The following table show the approximate amount of gas a well will deliver into a pipe line under different back line pressures when the rock pressure and the open flow of the wells, found by the Pitot tube, are given.

In taking the Pitot tube test, the well should be "blown off" for at least three hours prior to test. Due allowance is made for conserving the well and keeping the pressure high enough to prevent water coming in on the sand. The porosity of the different sands, and the depth of the different wells are taken into consideration.

These tables are also based on the assumption that there is no lead line between the well and the main line. Where lead lines are of any great length it will be found that the pressure at the main line will be less than at the well end of the lead line when the well is turned into the line. In this case the back pressure at the well end of the lead line is the pressure to be considered.

All capacities are given in cubic feet on a four-ounce basis for twenty-four hour periods.

Table No. 42—Flow in 1000 Cubic Feet From Gas Wells Against Different Line Pressures, Assuming the Actual Open Flow Capacity of the Wells to be One Mlilion Feet Daily

Back or Line Pressures Lb. per sq. in. Gauge	Full Rock Pressures (Lb. per sq. in. gauge)												
	100	150	200	250	300	350	400	500	600	700	800	900	1000
25	800	895	930	950	961	969	973	981	986	989	990	991	992
50	425	688	800	860	895	915	930	950	961	969	973	978	981
75	111	425	606	737	800	844	874	910	930	947	954	961	966
100	...	191	425	583	688	755	800	860	895	915	930	941	950
125	...	54	240	425	557	651	719	801	851	881	904	919	929
150	...	...	111	272	425	540	606	737	800	844	874	895	910
200	...	...	...	74	191	313	425	583	688	755	800	835	860
250	...	...	...	...	54	143	240	425	557	651	719	765	801
300	...	...	...	...	...	41	111	272	425	540	606	688	737
350	...	...	...	...	...	...	33	157	297	425	525	600	660
400	...	...	...	...	...	...	...	74	191	313	425	512	583
450	...	...	...	...	...	...	...	23	111	218	318	425	504
500	...	...	...	...	...	...	...	...	54	143	240	339	425
550	...	...	...	...	...	...	...	...	18	84	168	258	348
600	...	...	...	...	...	...	...	...	...	41	111	191	272
650	...	...	...	...	...	...	...	...	...	13	65	135	209
700	...	...	...	...	...	...	...	...	...	...	33	90	157
750	...	...	...	...	...	...	...	...	...	...	11	54	111
800	...	...	...	...	...	...	...	...	...	...	...	28	74
850	...	...	...	...	...	...	...	...	...	...	...	10	44
900	...	...	...	...	...	...	...	...	...	...	...	...	23
950	...	...	...	...	...	...	...	...	...	...	...	...	8

PART FIVE

PIPE LINE CONSTRUCTION

SURVEYING—CONSTRUCTION CAMP—DITCHING —BLASTING AND SHOOTING—SCREW PIPE LINE (*Section*)—PLAIN END PIPE LINE (*Section*) —PIPE LINE WORK (*Section*).

Surveying—In constructing a long gas line, a survey should be made, using 3-foot stakes driven into the ground every two hundred feet, each stake being numbered with even numbers from the starting point. In short lines that follow highways the measuring can be done with an automobile speedometer, or with a bicycle and cyclometer. If neither of these is available, tie a cord or piece of cloth on one of the spokes in the front wheel of an ordinary buckboard and count the revolutions while driving over the route the line is to follow. The revolutions of the wheel, multiplied by its circumference, will then give the distance traversed by the vehicle.

Construction Camp—It is very essential in building a camp outfit to make bunks, floorings, etc., so that they may be readily removed from one location to another. The regulation size tent is 28 feet by 14 feet and will accommodate sixteen to eighteen men. Folding cots are convenient to use.

The men employed in camp are as follows:—cook, flunkies (one flunkey to every thirty men) and one night watchman. It is the duty of the night watchman to pack the buckets for the following day.

A No. 11 blanket and a 72-inch by 50-inch comforter should be used.

The charge for board for men is usually deducted from their wages.

Ditching—The size of the ditch for different size gas lines is as follows:

TABLE No. 43

Size of Pipe	Depth in Inches	Width in Inches
3- and 4-inch	20	Shovel
6-inch	24	Width
8-inch	28	20
10-inch	30	22
12-inch	32	24
16-inch	36	26

Fig. 90—CONSTRUCTION GANG CAMP

In constructing a line through timber, the right of way should be cleared sixteen to twenty feet in width.

Allow for wagon track on one side of the location of the ditch. In ditching on side hills throw the dirt on the lower side.

The ditchers should be followed by the grading gang composed of from three to ten men. Their work is to straighten out, level and prepare the ditch for the tong gang.

Where it is not necessary to lay the line deep, as in the case of small lines, a large plow can be used. It is also often used in starting ditches for large lines.

Blasting and Shooting—In shooting use thirty per cent dynamite. "Dobie" shooting is commonly practiced and

Fig. 91—MESS TENT FOR A CONSTRUCTION GANG

consists in placing the dynamite on top of the rock, and covering it with mud. Dynamite should be thawed by placing near a fire and turning frequently. It should be thawed very gradually. In drilling for shots use 5 to 8 pound sledges or hammers. The drills should be 12, 18, 24, and 30 inches long, of $1\frac{1}{4}$-inch diameter.

Each shooting gang consists of three men called strikers. The shooting gang should be accompanied by a blacksmith and helper with a portable forge.

To Prepare a Shot—Cut open one stick of dynamite and insert the percussion cap on the end of a fuse, placing the fuse in the center of the stick and closing the stick together. Insert the dynamite in the shot hole, packing gently with a wooden stick and fill on top with mud.

The fuse should project twelve to eighteen inches from the hole where the shot is placed. Size of shot varies according to the character of the rock; generally from two to three sticks to a shot.

SCREW PIPE LINE

Pipe Unloading—In loading and unloading either screw or plain end pipe, great care should be used to protect the end of the pipe. Pipe should not be thrown off the car onto the ground or pile, but should be rolled off on skids. In unloading 10-inch or larger, a mast and tackle block with one horse for power should be used. The method of taking hold of the pipe is by means of a rope loop with two iron hooks to hook into the opposite ends of the pipe.

Tallying—All pipe should be tallied or measured when unloaded from the car. In measuring plain end pipe, measure the full length, while in measuring screw pipe, measure from thread end to center of collar.

Hauling—In the construction of large size lines, pipe is generally hauled under contract by the foot or by the joint.

All pipe should be carefully examined and defective joints thrown out before hauling to the right of way.

Where second-hand pipe is to be laid, its threads should be oiled and brushed with a wire brush.

Stringing—In stringing screw pipe, lay collar end in opposite direction from tong gang or starting point and allow for threads.

TABLE No. 44—STANDARD PIPE—BLACK AND GALVANIZED

All weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per Foot		Feet of Pipe for 1 Cu. Ft. Volume	Threads per Inch	Couplings		
	External	Internal		Plain Ends	Threads and Couplings			Diameter	Length	Weight
1/8	.405	.269	.068	.244	.245	2500.	27	.562	7/8	.029
1/4	.540	.364	.088	.424	.425	1385.	18	.685	1	.043
3/8	.675	.493	.091	.567	.568	751.5	18	.848	1 1/8	.070
1/2	.840	.622	.109	.850	.852	472.4	14	1.024	1 3/8	.116
3/4	1.050	.824	.113	1.130	1.134	270.	14	1.281	1 5/8	.209
1	1.315	1.049	.133	1.678	1.684	166.9	11 1/2	1.576	1 7/8	.343
1 1/4	1.660	1.380	.140	2.272	2.281	96.25	11 1/2	1.950	2 1/8	.535
1 1/2	1.900	1.610	.145	2.717	2.731	70.65	11 1/2	2.218	2 3/8	.743
2	2.375	2.067	.154	3.652	3.678	42.36	11 1/2	2.760	2 5/8	1.208
2 1/2	2.875	2.469	.203	5.793	5.819	30.11	8	3.276	2 7/8	1.720
3	3.500	3.068	.216	7.575	7.616	19.49	8	3.948	3 1/8	2.498
3 1/2	4.000	3.548	.226	9.109	9.202	14.56	8	4.591	3 5/8	4.241
4	4.500	4.026	.237	10.790	10.889	11.31	8	5.091	3 5/8	4.741
4 1/2	5.000	4.506	.247	12.538	12.642	9.03	8	5.591	3 5/8	5.241
5	5.563	5.047	.258	14.617	14.810	7.20	8	6.296	4 1/8	8.091
6	6.625	6.065	.280	18.974	19.185	4.98	8	7.358	4 1/8	9.554
7	7.625	7.023	.301	23.554	23.769	3.72	8	8.358	4 1/8	10.932
8	8.625	8.071	.277	24.696	25.000	2.88	8	9.358	4 5/8	13.905
8	8.625	7.981	.322	28.554	28.809		8	9.358	4 5/8	13.905
9	9.625	8.941	.342	33.907	34.188	2.26	8	10.358	5 1/8	17.236

STANDARD PIPE—BLACK AND GALVANIZED—*Continued.*

All weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per Foot		Feet of Pipe for 1 Cu. Ft. Volume	Threads per Inch	Couplings		
	External	Internal		Ends Plain	Threads and Couplings			Diameter	Length	Weight
10	10.750	10.192	.279	31.201	32.000	1.80	8	11.721	6⅛	29.877
10	10.750	10.136	.307	34.240	35.000		8	11.721	6⅛	29.877
10	10.750	10.020	.365	40.483	41.132		8	11.721	6⅛	29.877
11	11.750	11.000	.375	45.557	46.247		8	12.721	6⅛	32.550
12	12.750	12.090	.330	43.773	45.000	1.27	8	13.958	6⅛	43.098
12	12.750	12.000	.375	49.562	50.706		8	13.958	6⅛	43.098
13	14.000	13.250	.375	54.568	55.824		8	15.208	6⅛	47.152
14	15.000	14.250	.375	58.573	60.375		8	16.446	6⅛	59.493
15	16.000	15.250	.375	62.579	64.500		8	17.446	6⅛	63.294
17 O. D.	17.000	16.214	.393	69.704	72.602		8	18.683	7⅛	90.941
18 O. D.	18.000	17.182	.409	76.840	80.482		8	19.921	7⅛	108.672
20 O. D.	20.000	19.182	.409	85.577	89.617		8	21.921	7⅛	120.187

The permissible variation in weight is 5 per cent. above and 5 per cent. below.
Furnished with threads and couplings and in random lengths unless otherwise ordered.
Taper of threads is ¾ inch diameter per foot for all sizes.
The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.
All weights given in pounds. All dimensions given in inches.
On sizes made in more than one weight, weight desired must be specified.

TABLE No. 44—STANDARD PIPE—BLACK AND GALVANIZED

All weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per Foot		Feet of Pipe for 1 Cu. Ft. Volume	Threads per Inch	Couplings		
	External	Internal		Plain Ends	Threads and Couplings			Diameter	Length	Weight
1/8	.405	.269	.068	.244	.245	2500.	27	.562	7/8	.029
1/4	.540	.364	.088	.424	.425	1385.	18	.685	1	.043
3/8	.675	.493	.091	.567	.568	751.5	18	.848	1 1/8	.070
1/2	.840	.622	.109	.850	.852	472.4	14	1.024	1 3/8	.116
3/4	1.050	.824	.113	1.130	1.134	270.	14	1.281	1 5/8	.209
1	1.315	1.049	.133	1.678	1.684	166.9	11 1/2	1.576	1 7/8	.343
1 1/4	1.660	1.380	.140	2.272	2.281	96.25	11 1/2	1.950	2 1/8	.535
1 1/2	1.900	1.610	.145	2.717	2.731	70.65	11 1/2	2.218	2 3/8	.743
2	2.375	2.067	.154	3.652	3.678	42.36	11 1/2	2.760	2 5/8	1.208
2 1/2	2.875	2.469	.203	5.793	5.819	30.11	8	3.276	2 7/8	1.720
3	3.500	3.068	.216	7.575	7.616	19.49	8	3.948	3 1/8	2.498
3 1/2	4.000	3.548	.226	9.109	9.202	14.56	8	4.591	3 5/8	4.241
4	4.500	4.026	.237	10.790	10.889	11.31	8	5.091	3 5/8	4.741
4 1/2	5.000	4.506	.247	12.538	12.642	9.03	8	5.591	3 5/8	5.241
5	5.563	5.047	.258	14.617	14.810	7.20	8	6.296	4 1/8	8.091
6	6.625	6.065	.280	18.974	19.185	4.98	8	7.358	4 1/8	9.554
7	7.625	7.023	.301	23.554	23.769	3.72	8	8.358	4 1/8	10.932
8	8.625	8.071	.277	24.696	25.000	2.88	8	9.358	4 5/8	13.905
8	8.625	7.981	.322	28.554	28.809		8	9.358	4 5/8	13.905
9	9.625	8.941	.342	33.907	34.188	2.26	8	10.358	5 1/8	17.236

STANDARD PIPE—BLACK AND GALVANIZED—*Continued.*

All weights and Dimensions are Nominal

Size	Diameters		Thickness	Weight per Foot		Feet of Pipe for 1 Cu. Ft. Volume	Threads per Inch	Couplings		
	External	Internal		Ends Plain	Threads and Couplings			Diameter	Length	Weight
10	10.750	10.192	.279	31.201	32.000	1.80	8	11.721	6⅛	29.877
10	10.750	10.136	.307	34.240	35.000		8	11.721	6⅛	29.877
10	10.750	10.020	.365	40.483	41.132		8	11.721	6⅛	29.877
11	11.750	11.000	.375	45.557	46.247		8	12.721	6⅛	32.550
12	12.750	12.090	.330	43.773	45.000	1.27	8	13.958	6⅛	43.098
12	12.750	12.000	.375	49.562	50.706		8	13.958	6⅛	43.098
13	14.000	13.250	.375	54.568	55.824		8	15.208	6⅛	47.152
14	15.000	14.250	.375	58.573	60.375		8	16.446	6⅛	59.493
15	16.000	15.250	.375	62.579	64.500		8	17.446	6⅛	63.294
17 O. D.	17.000	16.214	.393	69.704	72.602		8	18.683	7⅛	90.941
18 O. D.	18.000	17.182	.409	76.840	80.482		8	19.921	7⅛	108.672
20 O. D.	20.000	19.182	.409	85.577	89.617		8	21.921	7⅛	120.187

The permissible variation in weight is 5 per cent. above and 5 per cent. below.
Furnished with threads and couplings and in random lengths unless otherwise ordered.
Taper of threads is ¾ inch diameter per foot for all sizes.
The weight per foot of pipe with threads and couplings is based on a length of 20 feet, including the coupling, but shipping lengths of small sizes will usually average less than 20 feet.
All weights given in pounds. All dimensions given in inches.
On sizes made in more than one weight, weight desired must be specified.

of ditch to position for stabbing. The "dope" man carries the asphaltum or "dope" and paints the collar threads just ahead of the tong gang.

For letting the pipe into the ditch after it has been set up, a wooden horse, built so that the legs will stand on either side of the ditch, and a snubbing rope are used. Only one wooden horse is necessary. The pipe is let down on the "growler board" which is placed under the collar of the joint just set up, to support the pipe above the ditch until the wooden horse can be moved ahead to a new position.

Painting—All pipe laid under ground should be painted, especially when second-hand casing is used for a gas line. Use a regular small-size "hot tar cart." The tar should be kept hot and put on the pipe with a brush swab after the pipe is set up and before it is lowered into the ditch.

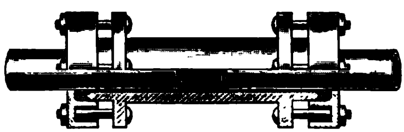


Fig. 97—EXPANSION SLEEVES

Laying Pipe in Level Country—In laying large-size high pressure pipe lines in level country use an expansion sleeve every mile or two. In case the line makes an abrupt angle, the tee should be anchored with a large rock or concrete bumper. This will prevent the line parting at the nearest sleeve.

Laying Pipe in Rough Country—Lay lines deep through any knoll or ridge, or, in other words, lay it as straight as possible with no more fire bends than are absolutely necessary. On steep inclines, put in "deadmen," or anchorages, the size and number depending upon the steepness and length of the incline. Also place bunches of underbrush, with branches pointing up hill, every fifty feet in the ditch and fill in on top of the brush. The underbrush prevents wash-

outs. Do not lay lines through "slips" or where there is any possibility of a "slip" in the future.

Bending Screw Pipe—To make an under or sag bend, set up one or two joints beyond the point to be bent, supporting the end above the ditch. Build a fire of wood (using some kerosene), about three feet long, covering the point to be bent on both sides of the pipe. The fire can be built underneath the pipe in the ditch, or in case the pipe is above the ditch, use a couple of hangers, with a sheet of iron suspended under the pipe where the bend is to come and build the fire on this. After being properly heated, bend the pipe by the weight of men. Care should be used that the pipe is not burned or buckled.

For over-bends, make a sag bend as above described and screw the joint of pipe one-half turn to bring the bend on top.

Rivers and Creeks—In laying lines through small rivers or creeks where the water contains injurious chemicals, the pipe should be encased in concrete. In crossing a river where concrete is not necessary, each joint of pipe should be weighted down with a cast iron clamp at the collar, as the pipe will float unless anchored. River "dogs" or hooks may also be used for anchoring the pipe.

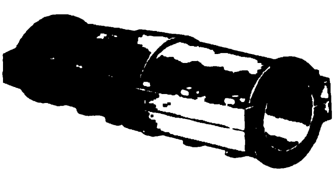


Fig. 98—RIVER CLAMP

In laying gas lines across shallow rivers or creeks where the lines are not cemented, they should be buried if possible and well covered with rock.

Railroad Crossings—Where the gas lines cross under railroad tracks, they should be run through a casing which should extend a few feet beyond either side of the track. This acts as a protection against the jar of passing trains, and in event of any leakage it carries the gas off to the side of the track.

Small Gas Lines—With small-size screw pipe lines, lay "snake like" to allow for expansion and contraction, in which case expansion sleeves are not necessary. This method consists in laying the pipe in a wavy line to permit the expansion or contraction to be taken up by the bending of the pipe.

PLAIN END PIPE

Plain End Pipe—Plain end pipe is the same as screw pipe except that it has no threads. Including couplers, it is a little more expensive than screw pipe, although the cost of laying is less than that of screw pipe.

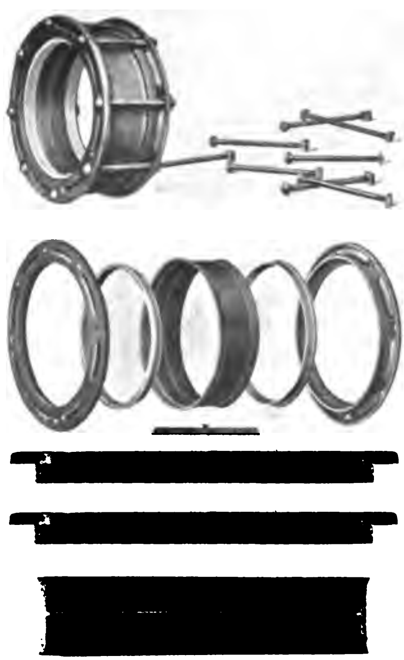


Fig 99—PLAIN END PIPE COUPLING SHOWING PARTS AND SECTIONAL VIEW OF RINGS

Hauling Plain End Pipe—In hauling plain end pipe, load one center ring and two end rings to each joint of pipe on the wagon. If the bolts are received in sacks, they should be distributed along the right of way according to the number required for each joint of pipe.

Fig. 100—PLAIN END PIPE COUPLING

Fig. 101—ALL-STEEL LONG SLEEVES
Sizes: 10 inches inside diameter to 18 inches outside diameter, inclusive, 16 inches long.

Stringing—In stringing plain end pipe, lay it with ends butting together.

Bending—Bending plain end pipe should be done before the pipe is set up and ahead of the laying gang.

In making bends distribute the fire for a distance of about three feet on both sides of the pipe and do not place the center block too near the fire. Apply greatest heat on the side of the pipe that is intended to stretch. After being sufficiently

Fig. 102—MAKING FIRE BEND
Using pipe tongs and chain on a two-inch pipe as a windlass. Large pipe is chained together at opposite end and block is placed between the chained end and the fire

heated the pipe should be bent gradually to prevent buckling. The boss of the bending gang should be a man of good judgment.

Laying—The pipe is put together on skids laid across the ditch. After placing the end ring and rubber on the end of the pipe, stab the joint into the center ring until the end of the pipe butts the bead in the center of the center ring. The outside rings should be bolted together while the pipe rest on the skids over the ditch and inspected in this position. In bolting up center rings, bolt four bolts equally distant first. Care should be taken that the two outside rings are equally distant at every point around the center ring. After ten or twelve joints are thus connected, all but the last joint or two can be lowered in the ditch by the use of wooden horses and snubbing rope. Ratchet wrenches should be used to tighten bolts. The bolts should be placed in the end rings so that the nuts will come on the left hand side of the center ring on either side of the pipe. This will allow the wrencher to work right-handed and with downward stroke, regardless of which side of the pipe he is working on.

Fig. 103—STABBING PLAIN END PIPE

Fig. 104—LOWERING SINGLE JOINTS OF PLAIN END PIPE INTO THE DITCH

In laying over hills or through gulleys, where deep ditching is impossible and angles are not sharp enough to require bending or the use of angle joints, use short joints of pipe, making a slight angle at each joint.

Creeks and Water-Soaked Ground—Where a line crosses creeks and is not cemented, screw pipe should be laid, and the same methods should be followed as given under the subject of screw pipe.

Fig. 105—LOWERING PLAIN END PIPE LINE INTO THE DITCH BY THE AID OF WOODEN HORSES AFTER BEING COUPLED TOGETHER

Plain end pipe laid in swampy or water-soaked ground should be well anchored with rocks to prevent blow-outs.

Whenever it develops that a plain end pipe line has been laid through land that is liable to inundation or is very wet and swampy at certain times of the year, it is policy to lay out a new survey beginning at the high points at either end

of the low ground, and if possible, run an extra line around on high ground to avoid any wash-outs or interruptions in the service of the high pressure line.

Rough Country—Do not lay plain end pipe down hill. Always start at the foot of the hill and lay up.

Angle Couplings—In place of bending, angle couplings can be used to advantage but must be well anchored with rock.

Fig. 106—PAINTING PLAIN END PIPE

Inspection and Leaks—One of the most important things to observe in the construction of a plain end pipe line, is the inspection of the couplings after being laid.

To repair leaks on plain end pipe under pressure, do not uncover more than one coupling at a time.

All center and end rings should be carefully inspected before laying.

Covering—The covering is done by a section of the ditching gang, after the pipe has been tested by the tong gang.

Do not cover a pipe line with cinders on account of the sulphur in them, they will corrode or pit the pipe, and rapidly destroy it.

Fig. 107—LAYING PLAIN END PIPE

PIPE LINE WORK

Inspection After Gas Line is Completed—After a gas line is completed and covered, attention should be given the work to note whether the filling has settled, or whether any washouts have occurred. The best time for making an inspection is directly following a hard rain.

A plain end pipe line under pressure requires a considable amount of covering to prevent blow-outs.

Line Walking—After a large high pressure gas line has been put into service, a line-walker should be employed for each fifteen or twenty miles of pipe, and he should inspect his allotted section of line daily. A great many companies construct a telephone line along the right of way, placing telephone boxes, under lock and key, every five or ten miles. Boxes should also be placed at railroad and river crossings and at all points where slips are liable to occur.

Fig. 108—SECTIONS OF A BROKEN GAS LINE

The blow out was caused by a farmer blowing out a stump with dynamite along side of the gas line. The result was several large cities were out of gas for two or three weeks.

If desired, installations can be made for telephone plugs, in which case the telephone stations can be placed about two miles apart. The line walker then carries a portable telephone outfit that can be "plugged in" at each of the stations.

Line Loss Percentage—The question is often asked—"What percentage of loss should we have in our low pressure system, even though the gas line is tight and services and meters have been carefully inspected?"

This is rather a difficult question to answer with any degree of accuracy.

It should be taken into consideration that a small leak on a gas line, even though it may be blown out by the use of a hat, means a continual loss of gas for not only twenty-four hours a day, but for three hundred and sixty-five days a year, and this co-called small leak will often supply a single consumer for a like period. Too much attention cannot be given to these small details. The gas leaking into the atmosphere means a continual loss in money. The fact that natural gas is a product of nature is postively no reason why it should be allowed to escape, regardless of where the leak may be, whether at the wells, on a line, or in house piping. Constant inspection of high and low pressure gas systems and the stoppage of all leakage found is the one method of conservation that is successful.

High Pressure Pipe Line Leakage—The mere fact that one has walked the full length of a buried pipe line (even though the line is laid but three or four inches beneath the surface) and has found or heard no leaks, does not furnish conclusive evidence of a tight gas line.

In testing for leaks some men use a torch, made by tying a small bundle of waste, saturated with kerosene, to the end of an eight or ten foot pole, and carrying it lighted over the full length of the line, holding the flame close to the top of the covered ditch. This method has met with success in some cases and is perfectly safe to the employee unless some exceptionally large leaks are met with. But it is not absolutely positive, and should not be used where a line shortage of any serious nature has developed.

It is taken for granted, in covering this particular subject, that a pipe line has been carefully tested for leaks by allowing high pressure gas to remain in it over night before placing the line in actual service. It is not always necessary to uncover every joint after a line is laid and covered. One

can find the leaks by driving a blunt-pointed bar at short intervals along the pipe line, and applying a torch to the hole made by the bar. In certain kinds of soil the leaking gas or heat of the sun often tends to form crust over a leaking joint, thereby forcing the leaking gas in different directions through the ground, and especially along the pipe, instead of directly to the surface. If, after driving the bar into the ground, the gas is found to burn at the openings made by it, the exact location of the main leak can be determined by the comparative size of the flames at the openings. As the holes appoach the main leak it will be noticed that the flames increase in size, thereby locating the point at which to make repairs. Oftentimes gas will travel along a pipe line many feet from the original point of leakage before coming to the surface.

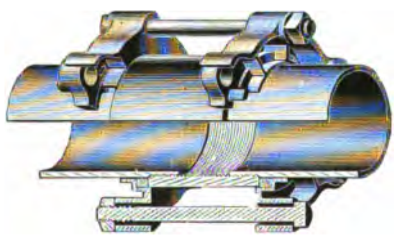


Fig. 109—COLLAR LEAK CLAMP

Certain kinds of soil, especially where cinders exist, have a chemical effect on the metal of the pipe, thereby causing the pitted effect commonly noticed. Cases have been known where pipe has been eaten through in a period of from one to two years time. If expansion sleeves are used in a pipe line and the line has any abrupt angles, unless the point at the angle is well anchored the expansion sleeves are apt to pull apart, due to the contraction of the pipe. It is well worth the cost and trouble to thoroughly inspect a high pressure gas

Fig. 110—WORKING ALONG A PIPE LINE LAID THROUGH SOFT OR SWAMPY GROUND. IN THIS CASE THE PLAIN END PIPE LINE BLEW OUT AND A SCREW LINE WAS LAID IN ITS PLACE

line at least once or twice a year. By the above statement it is meant to make a bar test over the whole line for leaks.

Lines should be kept free from dirt, water or other foreign substances. This is generally done with the great majority of pipe lines, yet in some cases the regulators as well as the meters will show dirt and water, whereas if the line had been kept clean this would have been eliminated. While large capacity meters or regulators will take care of a fair percentage of dirt and water without effecting their usefulness, it is not intended that they should measure dirt and water with a small percentage of gas.

The leakage from a pipe line is independent of the quantity of gas being passed through the line but is wholly dependent upon the pressures existing in the line. It can therefore amount to a very high percentage of the gas passed, in the case of a small flow and a high pressure, or again the percentage loss may be quite low when the volume of the flow is large and the pressure low.

Do not test a pipe line with a combination of air and gas. The pumping of air into a pipe line while there is gas in the line is apt to form the proper mixture for an explosion. Pebbles or scale blown along a line may cause sparks and this mixture of gas and air ignited has blown up miles of line.

The higher the gas pressure in pipe lines, the more apt the line is to leak.

Water in Pipe Lines—It is not uncommon to find instances where a great deal of free water has been drawn from drips or taps along a high pressure gas line, whereas practically no free water passed through the regulator or meter at the well in the field. This is explained by the fact that all natural gas carries more or less aqueous vapor which will not condense at the meter or regulator unless the temperature conditions are right, but which will condense at different points along the line, thereby forming free water. One pound of water at 62 deg. fahr. will make 1153 cubic feet of aqueous

Fig. 111—FILLING IN

vapor. While aqueous vapor should not account for any great loss in a measured volume of gas flowing between two points, there are cases where it should be taken into consideration, especially where there is a compressor. In the latter case a series of tanks or pipe returns are installed on the outlet side of the compressor to cool the gas, as well as to take care of the condensation. The compressor, while increasing the pressure of the gas, necessarily raises the temperature to a high degree, and in cooling, the aqueous vapor condenses wherever coming in contact with the pipe, which is kept at a lower temperature than the gas by the temperature of the atmosphere or water surrounding the cooling system. In the latter case it has proven good practice to install the outlet lines from a compressor through a pond. This has the desired effect and decreases the amount of the pipe required.

Fires on High Pressure Gas Lines Due to Leaks or Blow-outs—Small size fires can easily be put out by the use of a hand fire extinguisher. It is good policy for any gas company to have in an accessible location a hand chemical cart holding at least twenty-five gallons. This size cart will extinguish a fire or blaze from twenty to twenty-five feet high. Another method commonly practiced is to pile stone on the fire until the pile is three or four feet high, then turn a stream of water onto the heated stone. The effect is to create steam which smothers the flame.

Break in High Pressure Gas Line—If a break occurs in a high pressure line and shuts off the gas in a low pressure system, all gates at low pressure regulating points should be closed and the break repaired, after which all consumers should be notified at what hour the gas will be turned on again. If the break occurs in the night, it is better to keep the gas turned off until morning.

Fig. 112—AFTER A SCREW PIPE LINE IS LAID THROUGH SOFT OR SWAMPY GROUND IT SHOULD BE ANCHORED BY A ROCK FILL BETWEEN THE JOINTS

CHANGING A HIGH-PRESSURE LINE WITHOUT INTERRUPTION OF SERVICE.

In certain parts of Texas the soil is sandy and carries chemicals that in time will destroy any pipe line laid underground. This necessitates the renewal of portions of the pipe line from time to time in order to keep down the line loss or leakage. In Zapata and Webb Counties, Texas, the Border Gas Company has a forty-two mile, eight-inch high-pressure line that requires continual attention in order to keep it in good condition. Whenever a section of this line

Fig. 113—LINE READY TO MAKE THE CHANGE.

becomes pitted and leaky, a new section of one or two miles in length is laid parallel to and within a few inches of the old line and when completed the old line is broken opposite the ends of the new line and tied in with it. Generally a Sunday afternoon is selected to make the change when the consumption, both domestic and industrial, is lowest.

The author recently had opportunity of watching the operation of making a change and was very much impressed with the quickness of it and comparatively little loss of gas.

The line is an eight-inch plain-end pipe line, with gate valves every few miles, and is under 60-lb. pressure. The labor employed was Mexican. The new line had been completed the day before with the end joints opposite a coupling in the old line, so that it was only necessary, after breaking the coupling, to swing over the old line to connect with the new. This is best illustrated in Fig. 113. Both breaks were made simultaneously by two gangs. Communication was had by a portable telephone, not only between the two gangs but with the men at the gates two or three miles distant in each direction, and with the office in town.

Fig. 114—AFTER THE CENTER RING WAS BROKEN. MEXICANS WORKING IN THE CLOUD OF GAS AND DIRT.

The moment the two gate valves were closed, isolating the section to be changed, the center rings, which were cast iron, were broken with the aid of two sledge hammers. This immediately permitted the gas to flow from the line and naturally caused a cloud of dust, dirt and gravel. (See Fig. 114). The old line was pried over and the new connection made before all the gas had flowed from the old line. From

the time of starting to break the center ring to where the new section was connected tight, it required 58 seconds, while the other gang took 63 seconds.

All orders were given in Spanish, and it was interesting to note how quick the work was accomplished. The actual time the gate valves were closed and that section of line out of service was less than two minutes. During that time the domestic and industrial consumers were dependent upon the gas in the section of the line between the work and the city. At no time did the consumers know of the change through low pressure or a shortage of gas. There are some 2500

Fig. 115—CHANGE COMPLETED WITH GAS FLOWING THROUGH THE NEW SECTION OF LINE.

domestic consumers on the companies' lines. The industrial consumers would not be a factor, as the work was done on a Sunday afternoon. The distance from the city to nearest gate valve that was closed was about eight or nine miles.

Certain sections of this 42-mile line are laid about a foot above ground on iron supports, and covered with a bank of dirt every two or three joints. Where this can be done it is very satisfactory. The extreme heat during summer does not seem to throw the pipe out of line, due to the fact that each coupling acts as an expansion joint.

All pipe recently laid underground is painted with special paint and wound with tar paper.

Blow-offs and Drips—Place blow-offs or drips on the main field line in the immediate vicinity of the field wherever there is a depression or gulley. The regulation gas well drip can be used to advantage. The drip should be placed a little ahead of and higher than the lowest point of the depression or gulley. These drips or blow-offs should be visited often and kept free from water.

Gas tanks can be used on a gas line in place of drips. These tanks are built in different sizes with a baffle plate in the center against which the gas from the inlet line strikes in entering the tank.

The liquid in the gas is caught on the plate and drops to the bottom of the tank, while the gas passes around the plate and out of the tank, freed from its liquid.

Fig. 116
HIGH PRESSURE PIPE LINE SADDLE
Note—Sheet Lead makes the best Gasket

High Pressure Taps—In making a high pressure tap, cut out a circle of the size desired on the pipe with a diamond point chisel; then strap on the saddle with the nipple and gate set up in saddle. The circle should be cut in the pipe until the gas begins to leak. After the saddle and connections are strapped on, the center of the circle can be punched through and the gate closed.

Section

Figs. 117 and 118—CAST IRON GATE LOCKS

GATE VALVES

Gates left unboxed should have the wheel removed.

Open high pressure gates slowly when under pressure.

The objection to using stop-cocks on high pressure gas lines is that the core of the stop will often become corroded and stick, requiring the jarring of the small end of the core in order to turn it. This is a dangerous practice, especially if there is any frost in the metal.

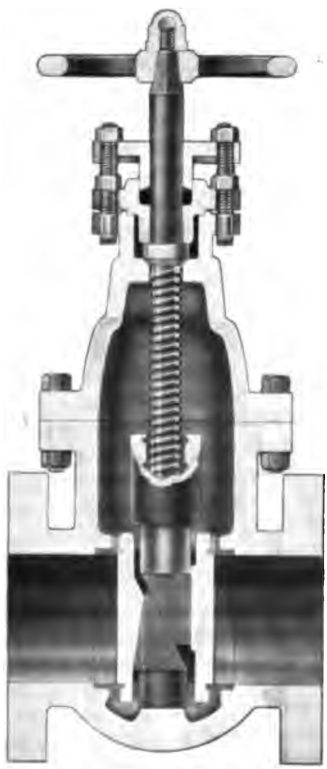


Fig. 119—SECTIONAL VIEW OF HIGH PRESSURE GATE VALVE

GATE VALVE STEMS

No doubt a very large percentage of leaky stuffing boxes in gate valves is due to bent stems. If a valve stem is bent the slightest, the bend will soon press aside the packing in the stuffing box and cause a leak.

Stems are generally bent by dropping the valve from a wagon or platform onto the ground. The valve will either land on the stem or on the body when it will roll over and and strike the stem. Wooden shipping crates are of some protection but should not be depended upon to protect the stem from injury.

TESTING GATE VALVES

Gate Valves are built for various pressures in addition to the many sizes. The method pursued in testing for defects is by closing both ends by plugs, if it is a screw type, or by blind flanges if it is a flange type. Water is then pumped into the gate valve by a small hand pump until the desired pressure is reached when a careful examination can be made for leaks caused by sand holes, blow holes or cracks. This test is for external leaks due to defects in the casting or to poor packing around the stem.

To test the valve for leaky disks, the plugs or blind flanges are removed and the disks closed tight by screwing in the stem; then the water is pumped through a tap which was made in the bottom of the body when the valve was being manufactured, until the proper pressure in the valve is reached when an examination can be made to see if the disks leak.

It is a well known fact that some gate valve manufacturers use the last described test, trusting to luck that the necks of valve, between body and hub or flange, carry no flaws or defects. Sometimes a flaw, or blow-hole of large size will form directly under the skin of the iron and could

not be noticed by the naked eye. In a case of this kind the first test described above would soon show it up, but where the last described test only was used—the valve might even be installed in a gas line under high pressure—it would "blow up" and possibly cause loss of life.

Fig. 120—HEAVY SPLIT SLEEVE

Some manufacturers place their catalogue number on the body of a gate valve. The purchasing agents or the actual buyers are no doubt familiar with the pressure that such a valve will safely hold what the number indicates, but the men in the field who are the ones that actually install it are not. It is the best and safest policy for the manufacturer to place the working pressure on the valve in large figures. The pressure at which the valve is tested should not be given either on the valve or in the catalogue. The purchaser generally assumes that the manufacturer has allowed a safe margin for safety (which is the margin between the working pressure and the pressure test). When both pressures are given even in the catalogue, the great trouble is that one man gets the two figures confused, or intentionally installs a valve on a line where the pressure is equal to its tested pressure, and if for some reason or other, there should be an increase of pressure of a few pounds, an accident occurs.

In short the actual users or the buyers of the valve should not know at what pressure the valve was tested and at the same time the factory should not reduce its factor of safety above the working pressure the valve is intended for.

Use nothing but high pressure fittings on a high pressure gas line and do not use bushings.

Common paste board or tar paper makes good gasket material for field use. In the event of a high pressure valve or stop-cock becoming coated with frost, do not attempt to knock the frost off with a hammer or wrench, but thaw it with warm water.

Do not attempt to caulk fittings on a gas line under high pressure.

For splits in a gas line, use an extra heavy cast iron clamp with stuffing box. For leaks in thin collars, use collar leak clamps. Caulking the collars, as a rule, will not make a permanent tight joint on account of the expansion and contraction of the pipe.

Gauge—In placing a high pressure gauge at a farm house or lease house, it should be mounted on the outside of the building so that it can be seen through the window. Do not place any high pressure lines on the inside of such a building.

Gauges should be tested at least twice a year, or oftener, when there is any reason to doubt their accuracy.

To check gauges for accuracy it is best to use a standard type of "dead" weight tester. One can use an inspector's test pump for this work in which case the test gauge should be sent to the factory periodically for test of accuracy.

House Regulators—For use at farm houses, lease houses, and on some high pressure lines where the consumers are widely separated, the house regulator is very necessary.

It is essential to keep the regulator housed or well boxed to prevent children and animals interfering with it or injuring it. The writer has seen chickens roosting on the arm of the weight type of regulator while the consumer was complaining of its unsatisfactory work.

If a regulator freezes, thaw it with warm water.

Fig. 121—DEAD WEIGHT TYPE OF HOUSE REGULATOR

Fig. 122—HOUSE SERVICE REGULATOR

In this regulator the valve is opened by a spring instead of a lever and weight.

The valve and the valve seat both can be easily taken out and replaced without taking the entire regulator apart.

This type of regulator is intended to work on pressures under 100 lbs. and reduce the pressure of the gas to a few ounces suitable for domestic consumption.

PART SIX

CAPACITIES OF PIPE LINES

Friction—There is no actual loss of gas in a pipe line as the result of friction. The effect of the friction is merely to produce a drop of pressure.

Pipe Line Capacities—No two pipe line formulas will check exactly with one another. They are intended only for practical purposes in determining the proper sizes of lines to carry a certain amount of gas, and not to check with a meter. So many different factors enter into the computations of pipe line flows as to prevent the use of the formula as a means of measuring with any degree of accuracy, and it is impossible to consider it as a check on the readings of a meter. No two pipe lines of the same nominal diameter and length are exactly alike when carefully calibrated, due to many causes, the principal one of which is that commerical pipe is not strictly of a uniform diameter, and accumulation of sediment and dirt will change not only the effective diameter of the pipe in varying amounts but also the co-efficient of friction of the flowing gas. Any deviation of the actual effective diameter from that assumed in using the formula results in a multiplied error in the computed flow, due to the fact that the flow is proportional to the diameter raised to the 2.542th power. Leakage varies in different lines due to different operating pressures, thus introducing a variable error, and it is seldom found that a condition of uniform flow obtains, which is assumed in the construction of all pipe line formulas. They should therefore be used only for determining the size of lines in designing pipe line systems, or for obtaining an idea of the pressures to be expected at various points under given flow conditions, or the approximate carrying capacity of the lines under given pressure conditions.

Examples Showing Application of Table No. 45—Suppose that a line is composed of 10-inch and 16-inch pipe, that there are 30 miles of the former and 20 miles of the latter, and that the pressure is 200 pounds at the end of the 10-inch section, next the source, and 25 pounds at the discharge end of the 16-inch section. After adding 15 pounds to each of the pressures to obtain the actual pressure, these become 215 and 40 pounds, respectively.

The formula is

$$Q = 42a\sqrt{\frac{P_1^2 - P_2^2}{l}}$$

$$\sqrt{P_1^2 - P_2^2} = \sqrt{215^2 - 40^2} = \sqrt{44{,}625} = 211.3$$

For 10-inch pipe the multiplier is $a = 350$, as given in Table No. 48. The length of equivalent 10-inch pipe is now to be determined, so that it can be substituted in the formula. One mile of 16-inch pipe is equivalent to 0.0915 mile of 10-inch, and 20 miles of 16-inch will therefore be equivalent to 30 + 1.83 = 31.83 miles of 10-inch pipe. The same result can be obtained another way, as follows: 1 mile of 10-inch pipe is equivalent to 10.94 miles of 16-inch. Hence 20 miles of 16-inch will be equivalent to $\frac{20.00}{10.94} = 1.83$ miles of 10-inch pipe.

The equivalent lengths thus determined remain the same for all variations of pressure at the intake and outlet.

By substituting the determined quantities, the equation

$$Q = 42 \times 350 \sqrt{\frac{44625.}{31.83}} \quad Q = 42 \times \frac{350 \times 211.3}{5.63} = 551{,}700$$

cubic feet per hour.

Suppose the pressure be increased to 400 pounds at the intake and 25 pounds at the outlet; then

$$\sqrt{415^2 - 40^2} = \sqrt{170{,}625} = 413$$

As compared with 211.3 this quantity would be 1.95 times 211.3, showing the increase in quantity to be almost directly

TABLE

COMPARATIVE CAPACITY OF PIPES OF DIFFERENT
GAS APPLIED TO LINES IN WHICH A

Size of Pipe In.	1	2	3	4	5	6	8
							Comparative
				Note—In making computations observe			
1	1	34	265	1,150	3,573	9,035	39,000
2	.0294	1	7.8	34	105	266	1,150
3	.0037	.128	1	4.34	13.45	34	147
4	....	.0295	.231	1	3.11	7.80	34
5	....	....	.0741	.3274	1	2.51	10.94
6	....	....	.0293	.1272	.3954	1	4.34
8	....	....	.0037	.0295	.0915	.2316	1
10	....	....	....	.0094	.0295	.0741	.3260
12	....	....	....	....	.0116	.0295	.1272
15¼	....	....	....	....	....	.0086	.0373
16	....	....	....	....	....	....	.0295
17¼	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....
19¼	....	....	....	....	....	....	....
20	....	....	....	....	....	....	....

The above table is based upon the fact that the length of pipes for the same quantity of gas varies as the 5.0835 power of their diameters. The value of the increasing or decreasing sizes can readily be appreciated by an inspection of the table.

It is particularly useful in securing the value of a series of different sizes of pipes in the same line by reducing the values of the several sizes to some one of the sizes in use. For example, on the horizontal line in the table a unit, say 1 foot or 1 mile of 8 inch pipe,

No. 45

DIAMETERS CONVEYING THE SAME QUANTITY OF NUMBER OF DIFFERENT SIZES ARE USED

(By F. H. Oliphant)

10	12	15¼	16	17¼	18	19¼	20

VALUES
carefully the decimal notations.

121,210	306,380	1,043,700	1,326,000	1,937,700	2,406,100	3,382,300	4,120,000
3,570	9,035	30,700	39,000	57,000	70,765	99,480	121,178
457	1,150	3,940	5,004	7,312	9,040	12,760	15,550
105	265	908	1,150	1,685	2,092	2,940	3,575
34	85.75	292	371	542.3	673.4	946.6	1,150
13.45	34	115.5	147	215	265	375	457
3.11	7.80	26.75	34	50	61.70	86.70	105
1	2.52	8.61	10.94	16	19.85	27.90	34
.3954	1	3.41	4.34	6.32	7.80	11.00	13.45
.1161	.2935	1	1.27	1.85	2.30	3.24	3.95
.0915	.2316	.7871	1	1.46	1.81	2.55	3.11
.0630	.1582	.5386	.6843	1	1.24	1.75	2.13
....	.1273	.4337	.5510	.8053	1	1.41	1.71
....	....	.3085	.3920	.5728	.7113	1	1.22
....	....	....	.3218	.4703	.5840	.8209	1

has the same value as 3.11 feet or miles of 10 inch, 7.80 feet or miles of 12 inch and 105 feet or miles of 20 inch.

When smaller sizes are used 1 foot or 1 mile of 8 inch pipe is equivalent to 0.2316 feet or mile of 6 inch pipe, etc.

Larger diameters, when compared to smaller, give the equivalent in an increased length, and smaller diameters give a less length when compared with a diameter assumed to be 1.

as the intake pressure when the outlet pressure is small by comparison with the intake.

The proof of this illustration can be shown by substituting the equivalent distance for the 16-inch pipe and the multiplier for the same instead of the 10-inch.

By referring to the table it will be found that 1 mile of 10-inch pipe is equivalent to 10.94 miles of 16-inch. Thirty miles of 10-inch are therefore equivalent to $30 \times 10.94 = 328$ miles of 16-inch. The whole line is consequently equivalent to $328 + 20 = 348$ miles of 16-inch pipe.

In the table of multipliers for diameters greater than one inch, opposite 16 we find 1160; then if the pressures remain 200 and 25 pounds respectively, as before,

$$Q = 42\sqrt{\frac{44625}{348}} \times 1160, Q = \frac{42 \times 211.3 \times 1160}{18.66} = 551{,}690$$

cubic feet per hour, which is almost exactly the same quantity as obtained before.

For any specific gravity other than 0.6, multiply the final result by

$$\sqrt{\frac{0.6}{\text{sp. gr. gas}}}$$

For temperatures of flowing gas when observed above 60 deg. fahr., deduct 1 per cent. for each 10 degrees, and add a like amount for temperatures less than 60 deg. fahr.

Reduction in Pressure of Natural Gas in Pipes, Owing to Fittings—The drop in pressure due to friction in ells, tees and globe valves of ordinary manufacture is allowed by an addition to the length of straight pipe.

The following table shows the additional length required to compensate for friction due to ells, and tees. For globe valves increase the values shown in the table by 50 per cent.

TABLE No. 46

Diameter of Pipe Inches	Additional Length, Feet	Diameter of Pipe Inches	Additional Length, Feet
1	1.5	6	27.0
1¼	2.0	7	29.3
1½	2.7	8	35.3
2	4.7	10	46.7
2½	6.7	12	58.7
3	8.7	15	76.7
3½	10.7	18	95.0
4	13.3	20	108.0
5	18.7	24	133.0

Table of Multipliers for Different Specific Gravities—The following correction factors apply to all computations of the Pitot tube and orifice measurements and of the flow of gas in pipes, when the formulae used are based on a standard specific gravity of gas of 0.60. In practice, the corrections for gravity are usually neglected unless accurate results are required.

TABLE No. 47—MULTIPLIERS FOR DIFFERENT SPECIFIC GRAVITIES

Specific Gravity	Multiplier	Specific Gravity	Multiplier
.75	.894	.6	1.000
.70	.925	.55	1.044
.65	.960	.50	1.095

Pipe Capacity—The capacities of pipe lines of different sizes vary, as

$$\sqrt{d^{5.0835}} = d^{2.542}$$

where d is the diameter. The area of a pipe varies as the square of the diameter, or as d^2.

Tables for Computing the Flow of Natural Gas in Pipe Lines—Based upon formula by F. H. Oliphant in "Production of Natural Gas in 1900," United States Geological Survey.

$$\text{Formula} - Q = 42a.\sqrt{\frac{P_1^2 - P_2^2}{L}}$$

Q = cubic feet per hour.
42 = constant.
a = computed value for diameters.
P_1 = gauge pressure + 15 pounds at intake end of line-
P_2 = gauge pressure + 15 pounds at discharge end of line.
L = length of line in miles.
For value of A, see Table of Multipliers.

Calculated for 1-inch pipe (flow in thousands of cubic feet) for 24 hours at normal pressure of 14.4 pounds.

Specific gravity of gas taken at 0.6. For any other specific gravity multiply final result by $\sqrt{\frac{0.6}{\text{sp. gr. gas}}}$

For other diameters, use the following multipliers for value a:

TABLE No. 48

¼ inch	.0317	2¼ inches	10.37	8 inches	198
½ inch	.1810	3 inches	16.50	10 inches	350
¾ inch	.5012	4 inches	34.10	12 inches	556
1 inch	1.0000	5 inches	60.00	16 inches	1160
1½ inches	2.9300	5⅝ inches	81.00	18 inches	1570
2 inches	5.9200	6 inches	95.00		

For pipes greater than 12 inches in diameter the measure is taken from the outside and for pipes of ordinary thickness the corresponding inside diameters and multipliers are as follows:

Outside	Inside	Multiplier
15 inch	14¼ inch	863
16 inch	15¼ inch	1025
18 inch	17¼ inch	1410
20 inch	19¼ inch	1860

For riveted or cast pipe with inside diameters as below, use multipliers opposite:

20 inch	2055	30 inch	5830
24 inch	3285	36 inch	9330

All pipe line capacity tables on pages 307 to 351 are based on the foregoing formula.

Capacity, in Cubic Feet, of 1″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	15	....	....	....	....	....	....	....	....	....	....	....
20	28	24	....	....	....	....	....	....	....	....	....	....
30	40	37	28	20	....	....	....	....	....	....	....	....
40	51	49	42	38	31	....	....	....	....	....	....	....
50	62	60	55	51	47	34	....	....	....	....	....	....
60	72	71	66	63	60	51	37	....	....	....	....	....
70	83	....	78	....	72	65	55	....	....	....	....	....
80	93	....	89	....	84	78	69	....	....	....	....	....
90	103	....	99	....	95	90	83	54	....	....	....	....
100	114	....	110	108	106	100	95	72	....	....	....	....
125	139	....	....	135	....	129	124	108	80	....	....	....
150	165	....	....	161	....	156	152	139	119	107	....	....
175	190	....	....	187	....	....	179	168	152	129	94	....
200	215	....	....	212	....	....	206	196	183	164	139	....
225	241	....	....	237	....	....	232	....	211	196	175	106
250	266	....	....	264	....	....	258	....	240	226	209	156
275	291	....	....	289	....	....	284	....	268	....	240	196
300	316	....	....	315	....	....	310	....	295	....	270	232
325	342	....	....	340	....	....	336	....	322	....	299	265
350	367	....	....	365	....	....	362	....	349	....	328	297
375	392	....	....	391	....	....	387	....	375	....	356	328
400	417	....	....	416	....	....	412	....	410	....	383	357

Capacity, in Cubic Feet, of 2″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	89	....	....	....	....	....	....	....	....	....	....	....
20	167	146	....	....	....	....	....	....	....	....	....	....
30	241	223	168	119	....	....	....	....	....	....	....	....
40	305	292	253	305	188	....	....	....	....	....	....	....
50	368	358	326	305	279	206	....	....	....	....	....	....
60	431	421	395	....	358	304	223	....	....	....	....	....
70	492	....	462	....	430	386	326	....	....	....	....	....
80	553	....	526	....	499	462	412	....	....	....	....	....
90	615	....	590	....	566	533	492	322	....	....	....	....
100	676	....	653	....	629	596	566	427	....	....	....	....
125	827	....	....	800	....	767	739	639	476	....	....	....
150	977	....	....	955	....	928	905	825	705	638	....	....
175	1,127	....	....	1,108	....	....	1,065	998	901	766	562	....
200	1,277	....	....	1,260	....	....	1,222	1,165	1,084	973	822	....
225	1,426	....	....	1,408	....	....	1,378	....	1,253	1,162	1,038	632
250	1,576	....	....	1,563	....	....	1,532	....	1,424	1,342	1,237	924
275	1,726	....	....	1,713	....	....	1,686	....	1,588	....	1,423	1,161
300	1,876	....	....	1,864	....	....	1,839	....	1,750	....	1,600	1,373
325	2,025	....	....	2,014	....	....	1,991	....	1,909	....	1,773	1,571
350	2,174	....	....	2,164	....	....	2,143	....	2,066	....	1,942	1,760
375	2,324	....	....	2,314	....	....	2,294	....	2,223	....	2,108	1,941
400	2,473	....	....	2,464	....	....	2,440	....	2,379	....	2,272	2,118

Capacity, in Cubic Feet, of 2″ Pipe Line 2 Miles Long, for 24 Hours

All capacities given in tnousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	118	103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	171	158	119	.....	.....	.....	.....	.....	.....	.....	.....	.....
40	216	207	159	133	96	.....	.....	.....	.....	.....	.....	.....
50	261	253	231	216	198	146	.....	.....	.....	.....	.....	.....
60	305	299	280	268	253	215	158	.....	.....	.....	.....	.....
70	349	.....	327	.....	305	274	231	.....	.....	.....	.....	.....
80	392	.....	373	.....	354	327	292	.....	.....	.....	.....	.....
90	436	.....	418	.....	401	378	349	228	.....	.....	.....	.....
100	479	.....	463	456	446	423	401	303	.....	.....	.....	.....
125	586	.....	.....	567	.....	544	524	453	333	.....	.....	.....
150	693	.....	.....	677	.....	658	642	585	500	452	.....	.....
175	799	.....	.....	785	.....	.....	755	708	639	543	398	.....
200	906	.....	.....	894	.....	.....	867	826	768	690	583	.....
225	1,011	.....	.....	998	.....	.....	977	.....	888	.....	736	448
250	1,118	.....	.....	1,110	.....	.....	1,087	.....	1,010	.....	877	655
275	1,224	.....	.....	1,215	.....	.....	1,196	.....	1,126	.....	1,009	823
300	1,330	.....	.....	1,322	.....	.....	1,304	.....	1,241	.....	1,135	974
325	1,436	.....	.....	1,428	.....	.....	1,412	.....	1,354	.....	1,258	1,114
350	1,542	.....	.....	1,535	.....	.....	1,520	.....	1,466	.....	1,378	1,248
375	1,648	.....	.....	1,641	.....	.....	1,627	.....	1,577	.....	1,495	1,377
400	1,754	.....	.....	1,748	.....	.....	1,730	.....	1,687	.....	1,611	1.502

Capacity, in Cubic Feet, of 2″ Pipe Line 3 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	96	84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	139	128	97	68	.....	.....	.....	.....	.....	.....	.....	.....
40	176	169	146	130	108	.....	.....	.....	.....	.....	.....	.....
50	213	206	189	176	161	119	.....	.....	.....	.....	.....	.....
60	249	243	228	.....	206	175	128	.....	.....	.....	.....	.....
70	284	.....	267	.....	248	223	188	.....	.....	.....	.....	.....
80	320	.....	304	.....	288	267	238	.....	.....	.....	.....	.....
90	355	.....	341	.....	327	308	284	186	.....	.....	.....	.....
100	390	.....	377	.....	363	344	327	246	.....	.....	.....	.....
125	478	.....	.....	462	.....	443	427	369	275	.....	.....	.....
150	564	.....	.....	552	.....	536	523	476	408	369	.....	.....
175	651	.....	.....	640	.....	.....	615	577	520	442	324	.....
200	738	.....	.....	728	.....	.....	706	673	626	562	475	.....
225	824	.....	.....	813	.....	.....	796	.....	724	672	600	365
250	911	.....	.....	903	.....	.....	886	.....	823	776	715	534
275	997	.....	.....	990	.....	.....	974	.....	918	.....	822	671
300	1,084	.....	.....	1,077	.....	.....	1,062	.....	1,011	.....	925	793
325	1,170	.....	.....	1,164	.....	.....	1,150	.....	1,103	.....	1,025	908
350	1,257	.....	.....	1,251	.....	.....	1,238	.....	1,194	.....	1,122	1,017
375	1,343	.....	.....	1,337	.....	.....	1,326	.....	1,285	.....	1,218	1,122
400	1,429	.....	.....	1,424	.....	.....	1,410	.....	1,375	.....	1,313	1,224

Capacity, in Cubic Feet, of 2″ Pipe Line 4 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	83	73	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	120	111	84	59	.....	.....	.....	.....	.....	.....	.....	.....
40	152	146	126	112	94	.....	.....	.....	.....	.....	.....	.....
50	184	178	163	152	139	103	.....	.....	.....	.....	.....	.....
60	215	210	197	.....	178	152	111	.....	.....	.....	.....	.....
70	246	.....	231	.....	215	193	163	.....	.....	.....	.....	.....
80	276	.....	263	.....	249	231	206	.....	.....	.....	.....	.....
90	307	.....	295	.....	283	266	246	161	.....	.....	.....	.....
100	337	.....	326	.....	314	298	283	213	.....	.....	.....	.....
125	413	.....	.....	400	.....	383	369	319	238	.....	.....	.....
150	488	.....	.....	477	.....	464	452	412	352	319	.....	.....
175	563	.....	.....	553	.....	.....	532	499	450	383	280	.....
200	638	.....	.....	630	.....	.....	611	582	542	486	411	.....
225	713	.....	.....	703	.....	.....	689	.....	626	581	519	316
250	788	.....	.....	781	.....	.....	766	.....	712	671	618	462
275	862	.....	.....	856	.....	.....	842	.....	794	.....	711	580
300	937	.....	.....	932	.....	.....	919	.....	874	.....	800	686
325	1,012	.....	.....	1,007	.....	.....	995	.....	954	.....	886	785
350	1,087	.....	.....	1,082	.....	.....	1,071	.....	1,033	.....	971	879
375	1,161	.....	.....	1,157	.....	.....	1,147	.....	1,111	.....	1,054	970
400	1,236	.....	.....	1,232	.....	.....	1,222	.....	1,189	.....	1,135	1,058

Capacity, in Cubic Feet, of 2″ Pipe Line 5 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	39	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	74	65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	107	99	75	53	.....	.....	.....	.....	.....	.....	.....	.....
40	136	130	112	100	84	.....	.....	.....	.....	.....	.....	.....
50	164	159	145	136	124	92	.....	.....	.....	.....	.....	.....
60	192	188	176	168	159	135	99	.....	.....	.....	.....	.....
70	220	.....	206	.....	192	172	145	.....	.....	.....	.....	.....
80	247	.....	235	.....	222	206	184	.....	.....	.....	.....	.....
90	274	.....	263	.....	252	238	219	143	.....	.....	.....	.....
100	301	.....	291	287	281	266	252	190	.....	.....	.....	.....
125	369	.....	.....	357	.....	342	330	285	212	.....	.....	.....
150	436	.....	.....	426	.....	414	404	368	315	285	.....	.....
175	503	.....	.....	494	.....	.....	475	445	402	342	250	.....
200	570	.....	.....	562	.....	.....	545	520	484	434	367	.....
225	636	.....	.....	628	.....	.....	615	.....	559	519	463	282
250	703	.....	.....	697	.....	.....	684	.....	636	.....	552	412
275	770	.....	.....	765	.....	.....	752	.....	709	.....	635	518
300	837	.....	.....	832	.....	.....	821	.....	781	.....	714	613
325	904	.....	.....	899	.....	.....	888	.....	852	.....	792	701
350	971	.....	.....	966	.....	.....	956	.....	922	.....	867	785
375	1,037	.....	.....	1,033	.....	.....	1,024	.....	992	.....	941	866
400	1,104	.....	.....	1,100	.....	.....	1,089	.....	1,062	.....	1,014	945

Capacity, in Cubic Feet, of 2″ Pipe Line 7 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	33											
20	63	55										
30	91	84	63	45								
40	115	110	95	85	71							
50	139	135	123	115	105	77						
60	162	159	149		135	114	84					
70	185		174		162	145	123					
80	208		198		188	174	155					
90	232		222		213	201	185	121				
100	255		246		237	225	213	161				
125	311			302	289	289	279	241	179			
150	368			360		350	341	311	266	240		
175	425			418			401	376	339	289	212	
200	481			475			461	439	409	367	310	
225	538			531			519		472	438	391	238
250	594			589			578		537	506	466	348
275	651			646			636		599		536	438
300	707			703			693		660		603	518
325	763			759			751		720		669	592
350	820			816			808		779		732	664
375	876			873			865		838		795	732
400	933			929			920		897		857	799

Capacity, in Cubic Feet, of 2″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	28											
20	52	46										
30	76	70	53	37								
40	96	92	80	71	59							
50	116	113	103	96	85	65						
60	136	133	125	119	113	96	70					
70	155		146		136	122	103					
80	175		166		158	146	130					
90	194		186		179	168	155	101				
100	213		206	203	199	188	179	135				
125	261			253		242	234	202	150			
150	309			302		293	286	261	223	202		
175	356			350			337	315	285	242	177	
200	404			399			386	368	343	308	260	
225	451			445			436		396	367	328	200
250	498			494			485		450		391	292
275	546			542			533		502		450	367
300	593			590			582		553		506	434
325	640			637			630		604		561	497
350	688			685			678		654		614	557
375	735			732			726		703		667	614
400	782			780			772		753		719	670

Capacity, in Cubic Feet, of 2″ Pipe Line 15 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	43	37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	62	57	43	30	.....	.....	.....	.....	.....	.....	.....	.....
40	78	75	65	58	48	.....	.....	.....	.....	.....	.....	.....
50	95	92	84	78	72	53	.....	.....	.....	.....	.....	.....
60	111	109	102	97	92	78	57	.....	.....	.....	.....	.....
70	127	.....	119	.....	111	99	84	.....	.....	.....	.....	.....
80	143	.....	136	.....	129	119	106	.....	.....	.....	.....	.....
90	158	.....	152	.....	146	137	127	83	.....	.....	.....	.....
100	174	.....	168	.....	162	154	146	110	.....	.....	.....	.....
125	213	.....	.....	206	.....	198	191	165	123	.....	.....	.....
150	252	.....	.....	246	.....	239	233	213	182	165	.....	.....
175	291	.....	.....	286	.....	.....	275	257	232	197	145	.....
200	330	.....	.....	325	.....	.....	315	301	280	251	212	.....
225	368	.....	.....	363	.....	.....	356	.....	323	300	268	163
250	407	.....	.....	404	.....	.....	396	.....	368	.....	319	238
275	446	.....	.....	442	.....	.....	435	.....	410	.....	367	300
300	484	.....	.....	481	.....	.....	475	.....	452	.....	413	354
325	523	.....	.....	520	.....	.....	514	.....	493	.....	458	406
350	562	.....	.....	559	.....	.....	553	.....	534	.....	502	454
375	600	.....	.....	598	.....	.....	593	.....	574	.....	544	501
400	639	.....	.....	637	.....	.....	630	.....	614	.....	587	547

Capacity, in Cubic Feet, of 3″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	249	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	465	407	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	673	622	470	332	.....	.....	.....	.....	.....	.....	.....	.....
40	851	814	705	628	525	.....	.....	.....	.....	.....	.....	.....
50	1,027	997	911	851	780	575	.....	.....	.....	.....	.....	.....
60	1,202	1,175	1,102	.....	997	848	622	.....	.....	.....	.....	.....
70	1,373	.....	1,288	.....	1,199	1,077	909	.....	.....	.....	.....	.....
80	1,543	.....	1,468	.....	1,392	1,288	1,150	.....	.....	.....	.....	.....
90	1,714	.....	1,646	.....	1,578	1,486	1,372	898	.....	.....	.....	.....
100	1,884	.....	1,821	.....	1,754	1,663	1,578	1,190	.....	.....	.....	.....
125	2,305	.....	.....	2,232	.....	2,140	2,062	1,782	1,327	.....	.....	.....
150	2,724	.....	.....	2,662	.....	2,587	2,523	2,300	1,967	1,779	.....	.....
175	3,141	.....	.....	3,088	.....	.....	2,968	2,782	2,511	2,135	1,566	.....
200	3,560	.....	.....	3,514	.....	.....	3,407	3,248	3,022	2,714	2,293	.....
225	3,976	.....	.....	3,925	.....	.....	3,841	.....	3,492	3,241	2,893	1,762
250	4,394	.....	.....	4,357	.....	.....	4,272	.....	3,971	3,742	3,449	2,576
275	4,811	.....	.....	4,776	.....	.....	4,700	.....	4,427	.....	3,966	3,236
300	5,229	.....	.....	5,197	.....	.....	5,125	.....	4,878	.....	4,462	3,828
325	5,644	.....	.....	5,614	.....	.....	5,550	.....	5,322	.....	4,944	4,380
350	6,062	.....	.....	6,034	.....	.....	5,974	.....	5,761	.....	5,415	4,906
375	6,478	.....	.....	6,451	.....	.....	6,396	.....	6,198	.....	5,877	5,412
400	6,893	.....	.....	6,870	.....	.....	6,802	.....	6,632	.....	6,333	5,904

Capacity, in Cubic Feet, of 3" Pipe Line 2 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	176	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	330	288	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	477	441	333	235	.....	.....	.....	.....	.....	.....	.....	.....
40	603	577	500	445	372	.....	.....	.....	.....	.....	.....	.....
50	728	707	646	603	553	408	.....	.....	.....	.....	.....	.....
60	852	833	782	.....	707	601	441	.....	.....	.....	.....	.....
70	974	.....	914	.....	850	764	645	.....	.....	.....	.....	.....
80	1,094	.....	1,041	.....	987	914	816	.....	.....	.....	.....	.....
90	1,216	.....	1,167	.....	1,119	1,054	973	636	.....	.....	.....	.....
100	1,336	.....	1,291	.....	1,244	1,179	1,119	844	.....	.....	.....	.....
125	1,634	.....	.....	1,582	.....	1,518	1,462	1,264	941	.....	.....	.....
150	1,932	.....	.....	1,888	.....	1,835	1,789	1,631	1,395	1,262	.....	.....
175	2,228	.....	.....	2,190	.....	.....	2,105	1,973	1,781	1,514	1,111	.....
200	2,525	.....	.....	2,492	.....	.....	2,416	2,303	2,143	1,924	1,626	.....
225	2,820	.....	.....	2,783	.....	.....	2,724	.....	2,476	2,298	2,052	1.250
250	3,116	.....	.....	3,090	.....	.....	3,030	.....	2,816	2,653	2,446	1,827
275	3,412	.....	.....	3,387	.....	.....	3,333	.....	3,139	.....	2,813	2,295
300	3,708	.....	.....	3,685	.....	.....	3,635	.....	3,459	.....	3,164	2,715
325	4,003	.....	.....	3,981	.....	.....	3,935	.....	3,774	.....	3,506	3,106
350	4,299	.....	.....	4,279	.....	.....	4,236	.....	4,085	.....	3,840	3,479
375	4,594	.....	.....	4,575	.....	.....	4,536	.....	4,395	.....	4,168	3,838
400	4,889	.....	.....	4,872	.....	.....	4,824	.....	4,703	.....	4,491	4,187

Capacity, in Cubic Feet, of 3" Pipe Line 3 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	144	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	269	235	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	389	359	272	192	.....	.....	.....	.....	.....	.....	.....	.....
40	492	471	407	363	303	.....	.....	.....	.....	.....	.....	.....
50	594	576	526	492	450	332	.....	.....	.....	.....	.....	.....
60	695	679	637	.....	576	490	359	.....	.....	.....	.....	.....
70	794	.....	745	.....	693	622	525	.....	.....	.....	.....	.....
80	892	.....	848	.....	804	745	665	.....	.....	.....	.....	.....
90	991	.....	951	.....	912	859	793	519	.....	.....	.....	.....
100	1,089	.....	1,052	.....	1,014	961	912	688	.....	.....	.....	.....
125	1,332	.....	.....	1,290	.....	1,237	1,192	1,030	767	.....	.....	.....
150	1,574	.....	.....	1,539	.....	1,495	1,458	1,329	1,137	1,028	.....	.....
175	1,816	.....	.....	1,785	.....	.....	1,716	1,608	1,451	1,234	905	.....
200	2,058	.....	.....	2,031	.....	.....	1,969	1,877	1,746	1,569	1,325	.....
225	2,298	.....	.....	2,268	.....	.....	2,220	.....	2,018	1,873	1,672	1,019
250	2,540	.....	.....	2,518	.....	.....	2,469	.....	2,295	2,163	1,993	1,489
275	2,781	.....	.....	2,761	.....	.....	2,716	.....	2,559	.....	2,292	1,870
300	3,022	.....	.....	3,004	.....	.....	2,963	.....	2,819	.....	2,579	2,213
325	3,262	.....	.....	3,245	.....	.....	3,208	.....	3,076	.....	2,858	2,532
350	3,504	.....	.....	3,487	.....	.....	3,453	.....	3,330	.....	3,130	2,836
375	3,744	.....	.....	3,729	.....	.....	3,697	.....	3,583	.....	3,397	3,128
400	3,985	.....	.....	3,971	.....	.....	3,932	.....	3,834	.....	3,661	3,412

Capacity, in Cubic Feet, of 3″ Pipe Line 4 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	124	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	232	203	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	336	311	235	166	.....	.....	.....	.....	.....	.....	.....	.....
40	425	407	352	314	262	.....	.....	.....	.....	.....	.....	.....
50	513	498	455	425	390	287	.....	.....	.....	.....	.....	.....
60	601	587	551	.....	498	424	311	.....	.....	.....	.....	.....
70	686	.....	644	.....	599	538	454	.....	.....	.....	.....	.....
80	771	.....	734	.....	696	644	575	.....	.....	.....	.....	.....
90	857	.....	823	.....	789	760	703	449	.....	.....	.....	.....
100	942	.....	910	.....	877	831	789	595	.....	.....	.....	.....
125	1,152	.....	.....	1,116	.....	1,070	1,031	891	663	.....	.....	.....
150	1,362	.....	.....	1,331	.....	1,293	1,261	1,150	983	889	.....	.....
175	1,570	.....	.....	1,544	.....	.....	1,484	1,391	1,255	1,067	783	.....
200	1,780	.....	.....	1,757	.....	.....	1,703	1,624	1,511	1,357	1,146	.....
225	1,988	.....	.....	1,962	.....	.....	1,920	.....	1,746	1,620	1,446	881
250	2,197	.....	.....	2,178	.....	.....	2,136	.....	1,985	1,871	1,724	1,288
275	2,405	.....	.....	2,388	.....	.....	2,350	.....	2,213	.....	1,983	1,618
300	2,614	.....	.....	2,598	.....	.....	2,562	.....	2,439	.....	2,231	1,914
325	2,822	.....	.....	2,807	.....	.....	2,775	.....	2,661	.....	2,472	2,190
350	3,031	.....	.....	3,017	.....	.....	2,987	.....	2,880	.....	2,707	2,453
375	3,239	.....	.....	3,225	.....	.....	3,198	.....	3,099	.....	2,938	2,706
400	3,446	.....	.....	3,435	.....	.....	3,401	.....	3,316	.....	3,166	2,952

Capacity, in Cubic Feet, of 3″ Pipe Line 5 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	111	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	207	181	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	300	277	210	148	.....	.....	.....	.....	.....	.....	.....	.....
40	380	363	314	280	234	.....	.....	.....	.....	.....	.....	.....
50	458	445	406	380	348	256	.....	.....	.....	.....	.....	.....
60	536	524	492	470	445	378	.....	.....	.....	.....	.....	.....
70	613	.....	575	.....	535	481	406	.....	.....	.....	.....	.....
80	689	.....	655	.....	621	575	513	.....	.....	.....	.....	.....
90	765	.....	735	.....	704	663	612	400	.....	.....	.....	.....
100	841	.....	813	.....	783	742	704	531	.....	.....	.....	.....
125	1,029	.....	.....	996	.....	955	920	795	592	.....	.....	.....
150	1,216	.....	.....	1,188	.....	1,155	1,126	1,026	878	794	.....	.....
175	1,402	.....	.....	1,378	.....	.....	1,325	1,242	1,121	953	699	.....
200	1,589	.....	.....	1,568	.....	.....	1,521	1,450	1,349	1,211	1,023	.....
225	1,775	.....	.....	1,752	.....	.....	1,715	.....	1,559	1,447	1,291	787
250	1,961	.....	.....	1,945	.....	.....	1,907	.....	1,773	1,670	1,539	1,150
275	2,148	.....	.....	2,132	.....	.....	2,098	.....	1,976	.....	1,770	1,444
300	2,334	.....	.....	2,320	.....	.....	2,288	.....	2,177	.....	1,992	1,709
325	2,520	.....	.....	2,506	.....	.....	2,477	.....	2,376	.....	2,207	1,955
350	2,706	.....	.....	2,693	.....	.....	2,667	.....	2,572	.....	2,417	2,190
375	2,892	.....	.....	2,880	.....	.....	2,855	.....	2,767	.....	2,623	2,416
400	3,077	.....	.....	3,067	.....	.....	3,036	.....	2,961	.....	2,827	2,635

Capacity, in Cubic Feet, of 3″ Pipe Line 7 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	94	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	175	153	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	254	234	177	125	.....	.....	.....	.....	.....	.....	.....	.....
40	321	307	266	237	198	.....	.....	.....	.....	.....	.....	.....
50	387	376	343	321	294	217	.....	.....	.....	.....	.....	.....
60	453	443	416	.....	376	320	.....	.....	.....	.....	.....	.....
70	518	.....	486	.....	452	406	343	.....	.....	.....	.....	.....
80	582	.....	554	.....	525	486	434	.....	.....	.....	.....	.....
90	647	.....	621	.....	595	561	517	338	.....	.....	.....	.....
100	711	.....	687	.....	662	627	595	449	.....	.....	.....	.....
125	869	.....	.....	842	.....	807	778	672	500	.....	.....	.....
150	1,028	.....	.....	1,004	.....	976	952	867	742	671	.....	.....
175	1,185	.....	.....	1,165	.....	.....	1,120	1,049	947	805	591	.....
200	1,343	.....	.....	1,326	.....	.....	1,285	1,225	1,140	1,024	865	.....
225	1,500	.....	.....	1,481	.....	.....	1,449	.....	1,317	1,223	1,092	665
250	1,658	.....	.....	1,644	.....	.....	1,612	.....	1,498	1,412	1,301	972
275	1,815	.....	.....	1,802	.....	.....	1,773	.....	1,670	.....	1,496	1,221
300	1,973	.....	.....	1,961	.....	.....	1,934	.....	1,840	.....	1,683	1,444
325	2,130	.....	.....	2,118	.....	.....	2,094	.....	2,008	.....	1,865	1,653
350	2,287	.....	.....	2,276	.....	.....	2,254	.....	2,174	.....	2,043	1,851
375	2,444	.....	.....	2,434	.....	.....	2,413	.....	2,339	.....	2,217	2,042
400	2,601	.....	.....	2,592	.....	.....	2,566	.....	2,502	.....	2,389	2,227

Capacity, in Cubic Feet, of 3″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	78	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	147	128	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	213	196	148	105	.....	.....	.....	.....	.....	.....	.....	.....
40	269	257	223	198	166	.....	.....	.....	.....	.....	.....	.....
50	325	315	288	269	246	182	.....	.....	.....	.....	.....	.....
60	380	372	348	333	315	268	196	.....	.....	.....	.....	.....
70	434	.....	407	.....	379	341	287	.....	.....	.....	.....	.....
80	488	.....	464	.....	440	407	364	.....	.....	.....	.....	.....
90	542	.....	521	.....	449	470	434	284	.....	.....	.....	.....
100	596	.....	576	.....	555	526	499	376	.....	.....	.....	.....
125	729	.....	.....	706	.....	677	652	564	419	.....	.....	.....
150	862	.....	.....	842	.....	818	798	727	622	563	.....	.....
175	994	.....	.....	977	.....	.....	939	880	794	675	495	.....
200	1,126	.....	.....	1,112	.....	.....	1,078	1,027	956	858	725	.....
225	1,258	.....	.....	1,242	.....	.....	1,215	.....	1,105	1,025	915	557
250	1,310	.....	.....	1,378	.....	.....	1,352	.....	1,256	1,184	1,091	815
275	1,522	.....	.....	1,511	.....	.....	1,487	.....	1,401	.....	1,255	1,024
300	1,654	.....	.....	1,644	.....	.....	1,622	.....	1,543	.....	1,412	1,211
325	1,786	.....	.....	1,776	.....	.....	1,756	.....	1,684	.....	1,564	1,386
350	1,918	.....	.....	1,909	.....	.....	1,890	.....	1,823	.....	1,713	1,552
375	2,040	.....	.....	2,041	.....	.....	2,024	.....	1,961	.....	1,859	1,712
400	2,181	.....	.....	2,174	.....	.....	2,152	.....	2,098	.....	2,004	1,868

Capacity, in Cubic Feet, of 3″ Pipe Line 15 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	64	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	120	105	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	174	160	121	85	.....	.....	.....	.....	.....	.....	.....	.....
40	220	210	182	162	135	.....	.....	.....	.....	.....	.....	.....
50	265	257	235	220	201	148	.....	.....	.....	.....	.....	.....
60	310	303	284	272	257	219	160	.....	.....	.....	.....	.....
70	355	.....	333	.....	309	278	235	.....	.....	.....	.....	.....
80	398	.....	379	.....	359	333	297	.....	.....	.....	.....	.....
90	443	.....	425	.....	407	384	354	232	.....	.....	.....	.....
100	486	.....	470	.....	453	429	407	307	.....	.....	.....	.....
125	595	.....	.....	576	.....	553	532	460	342	.....	.....	.....
150	704	.....	.....	688	.....	668	652	594	508	459	.....	.....
175	811	.....	.....	798	.....	.....	767	719	648	551	404	.....
200	920	.....	.....	908	.....	.....	880	839	780	701	592	.....
225	1,027	.....	.....	1,014	.....	.....	992	.....	902	837	747	455
250	1,135	.....	.....	1,126	.....	.....	1,104	.....	1,026	967	891	665
275	1,243	.....	.....	1,234	.....	.....	1,214	.....	1,144	.....	1,025	836
300	1,351	.....	.....	1,343	.....	.....	1,324	.....	1,260	.....	1,153	989
325	1,458	.....	.....	1,451	.....	.....	1,434	.....	1,375	.....	1,277	1,132
350	1,566	.....	.....	1,559	.....	.....	1,543	.....	1,488	.....	1,399	1,267
375	1,674	.....	.....	1,667	.....	.....	1,653	.....	1,601	.....	1,518	1,398
400	1,781	.....	.....	1,775	.....	.....	1,757	.....	1,713	.....	1,635	1,525

Capacity, in Cubic Feet, of 3″ Pipe Line 25 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	93	81	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	134	124	94	66	.....	.....	.....	.....	.....	.....	.....	.....
40	170	162	141	125	105	.....	.....	.....	.....	.....	.....	.....
50	205	199	182	170	155	115	.....	.....	.....	.....	.....	.....
60	240	235	220	210	199	169	124	.....	.....	.....	.....	.....
70	274	.....	257	.....	239	215	181	.....	.....	.....	.....	.....
80	308	.....	293	.....	278	257	230	.....	.....	.....	.....	.....
90	342	.....	329	.....	315	297	274	179	.....	.....	.....	.....
100	376	.....	364	.....	350	332	315	238	.....	.....	.....	.....
125	460	.....	.....	446	.....	428	412	356	265	.....	.....	.....
150	544	.....	.....	532	.....	517	504	459	393	355	.....	.....
175	628	.....	.....	617	.....	.....	593	556	502	427	313	.....
200	712	.....	.....	702	.....	.....	681	649	604	542	458	.....
225	795	.....	.....	784	.....	.....	768	.....	698	648	578	352
250	878	.....	.....	871	.....	.....	854	.....	794	748	689	515
275	962	.....	.....	955	.....	.....	939	.....	885	.....	793	647
300	1,045	.....	.....	1,039	.....	.....	1,025	.....	975	.....	892	765
325	1,128	.....	.....	1,122	.....	.....	1,109	.....	1,064	.....	988	876
350	1,212	.....	.....	1,206	.....	.....	1,194	.....	1,152	.....	1,082	981
375	1,295	.....	.....	1,290	.....	.....	1,279	.....	1,239	.....	1,175	1,082
400	1,378	.....	.....	1,373	.....	.....	1,360	.....	1,326	.....	1,266	1,180

Capacity, in Cubic Feet, of 4″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	515	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	962	842	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,392	1,285	972	687	.....	.....	.....	.....	.....	.....	.....	.....
40	1,759	1,684	1,457	1,299	1,086	.....	.....	.....	.....	.....	.....	.....
50	2,124	2,062	1,883	1,759	1,612	1,189	.....	.....	.....	.....	.....	.....
60	2,485	2,430	2,278	.....	2,062	1,752	1,285	.....	.....	.....	.....	.....
70	2,839	.....	2,663	.....	2,478	2,227	1,880	.....	.....	.....	.....	.....
80	3,189	.....	3,035	.....	2,876	2,663	2,378	.....	.....	.....	.....	.....
90	3,543	.....	3,402	.....	3,261	3,072	2,835	1,856	.....	.....	.....	.....
100	3,894	.....	3,763	.....	3,626	3,437	3,261	2,461	.....	.....	.....	.....
125	4,763	.....	.....	4,612	.....	4,423	4,262	3,684	2,742	.....	.....	.....
150	5,630	.....	.....	5,502	.....	5,348	5,214	4,753	4,066	3,677	.....	.....
175	6,492	.....	.....	6,382	.....	.....	6,135	5,750	5,190	4,413	3,237	.....
200	7,359	.....	.....	7,262	.....	.....	7,042	6,712	6,245	5,607	4,739	.....
225	8,218	.....	.....	8,111	.....	.....	7,939	.....	7,218	6,699	5,980	3,643
250	9,081	.....	.....	9,005	.....	.....	8,830	.....	8,208	7,733	7,128	5,324
275	9,943	.....	.....	9,871	.....	.....	9,712	.....	9,149	.....	8,197	6,688
300	10,806	.....	.....	10,741	.....	.....	10,593	.....	10,081	.....	9,222	7,912
325	11,665	.....	.....	11,603	.....	.....	11,469	.....	10,999	.....	10,218	9,053
350	12,528	.....	.....	12,470	.....	.....	12,346	.....	11,906	.....	11,191	10,139
375	13,387	.....	.....	13,332	.....	.....	13,219	.....	12,810	.....	12,147	11,184
400	14,247	.....	.....	14,199	.....	.....	13,058	.....	13,707	.....	13,088	12,202

Capacity, in Cubic Feet, of 4″ Pipe Line 2 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	365	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	682	597	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	987	911	689	487	.....	.....	.....	.....	.....	.....	.....	.....
40	1,248	1,194	1,033	921	770	.....	.....	.....	.....	.....	.....	.....
50	1,506	1,462	1,335	1,248	1,143	843	.....	.....	.....	.....	.....	.....
60	1,762	1,723	1,616	.....	1,462	1,243	911	.....	.....	.....	.....	.....
70	2,013	.....	1,889	.....	1,757	1,579	1,333	.....	.....	.....	.....	.....
80	2,262	.....	2,152	.....	2,040	1,889	1,686	.....	.....	.....	.....	.....
90	2,513	.....	2,413	.....	2,313	2,179	2,011	1,316	.....	.....	.....	.....
100	2,762	.....	2,669	.....	2,571	2,437	2,313	1,745	.....	.....	.....	.....
125	3,378	.....	.....	3,271	.....	3,137	3,022	2,613	1,945	.....	.....	.....
150	3,993	.....	.....	3,902	.....	3,793	3,698	3,371	2,883	2,608	.....	.....
175	4,605	.....	.....	4,526	.....	.....	4,351	4,078	3,681	3,130	2,296	.....
200	5,219	.....	.....	5,151	.....	.....	4,995	4,761	4,429	3,978	3,361	.....
225	5,828	.....	.....	5,753	.....	.....	5,631	.....	5,119	4,751	4,241	2,584
250	6,440	.....	.....	6,387	.....	.....	6,262	.....	5,821	5,485	5,055	3,776
275	7,052	.....	.....	7,001	.....	.....	6,889	.....	6,489	.....	5,814	4,743
300	7,664	.....	.....	7,618	.....	.....	7,513	.....	7,150	.....	6,540	5,611
325	8,273	.....	.....	8,230	.....	.....	8,134	.....	7,800	.....	7,247	6,421
350	8,885	.....	.....	8,844	.....	.....	8,756	.....	8,444	.....	7,937	7,191
375	9,495	.....	.....	9,456	.....	.....	9,375	.....	9,085	.....	8,615	7,932
400	10,104	.....	.....	10,070	.....	.....	9,970	.....	9,721	.....	9,283	8,654

Capacity, in Cubic Feet, of 4″ Pipe Line 3 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	298	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	556	486	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	804	743	562	397	.....	.....	.....	.....	.....	.....	.....	.....
40	1,017	973	842	751	627	.....	.....	.....	.....	.....	.....	.....
50	1,227	1,192	1,088	1,017	931	687	.....	.....	.....	.....	.....	.....
60	1.436	1,404	1,317	.....	1,192	1,013	743	.....	.....	.....	.....	.....
70	1,641	.....	1,539	.....	1,432	1,287	1,086	.....	.....	.....	.....	.....
80	1,843	.....	1,754	.....	1,663	1,539	1,375	.....	.....	.....	.....	.....
90	2,048	.....	1,967	.....	1,885	1,776	1,639	1,072	.....	.....	.....	.....
100	2,251	.....	2,175	.....	2,096	1,987	1,885	1,422	.....	.....	.....	.....
125	2,753	.....	.....	2,666	.....	2,557	2,463	2,130	1,585	.....	.....	.....
150	3,254	.....	.....	3,181	.....	3,091	3,014	2,748	2,350	2,126	.....	.....
175	3,753	.....	.....	3,689	.....	.....	3,546	3,324	3,000	2,551	1,871	.....
200	4,254	.....	.....	4,198	.....	.....	4,071	3,880	3,610	3,242	2,740	.....
225	4,750	.....	.....	4,689	.....	.....	4,589	.....	4,172	3,872	3,457	2,106
250	5,249	.....	.....	5,205	.....	.....	5,104	.....	4,744	4,470	4,121	3,077
275	5,748	.....	.....	5,706	.....	.....	5,615	.....	5,289	.....	4,738	3,866
300	6,247	.....	.....	6,209	.....	.....	6,123	.....	5,827	.....	5,331	4,574
325	6,743	.....	.....	6,708	.....	.....	6,630	.....	6,358	.....	5,907	5,233
350	7,242	.....	.....	7,208	.....	.....	7,137	.....	6,882	.....	6,469	5,861
375	7,739	.....	.....	7,707	.....	.....	7,642	.....	7,405	.....	7,022	6,465
400	8,236	.....	.....	8,208	.....	.....	8,126	.....	7,924	.....	7,566	7,053

Capacity, in Cubic Feet, of 4″ Pipe Line 4 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	257	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	481	421	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	696	642	486	343	.....	.....	.....	.....	.....	.....	.....	.....
40	879	842	728	649	543	.....	.....	.....	.....	.....	.....	.....
50	1,062	1,031	941	879	806	594	.....	.....	.....	.....	.....	.....
60	1,242	1,215	1,139	.....	1,031	876	642	.....	.....	.....	.....	.....
70	1,419	.....	1,331	.....	1,239	1,113	940	.....	.....	.....	.....	.....
80	1,594	.....	1,517	.....	1,438	1,331	1,189	.....	.....	.....	.....	.....
90	1 771	.....	1,701	.....	1,630	1,536	1,417	928	.....	.....	.....	.....
100	1,947	.....	1,881	.....	1,813	1,718	1,630	1,230	.....	.....	.....	.....
125	2,381	.....	.....	2,306	.....	2,211	2,131	1,842	1,371	.....	.....	.....
150	2,815	.....	.....	2,751	.....	2,674	2,607	2,376	2,033	1,838	.....	.....
175	3,246	.....	.....	3,191	.....	.....	3,067	2,875	2,595	2,206	1,618	.....
200	3,679	.....	.....	3,631	.....	.....	3,521	3,356	3,122	2,804	2,369	.....
225	4,109	.....	.....	4,055	.....	.....	3,969	.....	3 609	3,349	2,990	1,821
250	4,540	.....	.....	4,502	.....	.....	4,415	.....	4,104	3,866	3,564	2,662
275	4,971	.....	.....	4,935	.....	.....	4,856	.....	4,574	.....	4,098	3,344
300	5,403	.....	.....	5,370	.....	.....	5 296	.....	5,040	.....	4,611	3,956
325	5,832	.....	.....	5,801	.....	.....	5,734	.....	5,499	.....	5,109	4,526
350	6,264	.....	.....	6,235	.....	.....	6,173	.....	5,953	.....	5,595	5,069
375	6,693	.....	.....	6,666	.....	.....	6,609	.....	6,405	.....	6,073	5,592
400	7,123	.....	.....	7,099	.....	.....	7,029	.....	6,853	.....	6,544	6,101

Capacity, in Cubic Feet, of 4" Pipe Line 5 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	230	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	429	375	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	621	573	434	306	.....	.....	.....	.....	.....	.....	.....	.....
40	785	751	659	580	484	.....	.....	.....	.....	.....	.....	.....
50	948	920	840	785	719	530	.....	.....	.....	.....	.....	.....
60	1,109	1,084	1,017	972	920	782	573	.....	.....	.....	.....	.....
70	1,267	.....	1,189	.....	1,106	994	839	.....	.....	.....	.....	.....
80	1,424	.....	1,354	.....	1,284	1,189	1,061	.....	.....	.....	.....	.....
90	1,582	.....	1,519	.....	1,456	1,371	1,265	828	.....	.....	.....	.....
100	1,738	.....	1,680	.....	1,618	1,534	1,456	1,098	.....	.....	.....	.....
125	2,126	.....	.....	2,059	.....	1,974	1,902	1,644	1,224	.....	.....	.....
150	2,513	.....	.....	2,456	.....	2,387	2,327	2,122	1,815	1,641	.....	.....
175	2,898	.....	.....	2,849	.....	.....	2,739	2,567	2,317	1,970	1,445	.....
200	3,285	.....	.....	3,242	.....	.....	3,144	2,996	2,788	2,504	2,116	.....
225	3,668	.....	.....	3,621	.....	.....	3,544	.....	3,222	2,990	2,670	1,626
250	4,054	.....	.....	4,020	.....	.....	3,942	.....	3,664	3,452	3,182	2,376
275	4,439	.....	.....	4,407	.....	.....	4,336	.....	4,084	.....	3,659	2,986
300	4,824	.....	.....	4,795	.....	.....	4,729	.....	4,500	.....	4,117	3,532
325	5,208	.....	.....	5,180	.....	.....	5,120	.....	4,910	.....	4,562	4,041
350	5,593	.....	.....	5,567	.....	.....	5,511	.....	5,315	.....	4,996	4,526
375	5,976	.....	.....	5,952	.....	.....	5,901	.....	5,719	.....	5,422	4,993
400	6,360	.....	.....	6,339	.....	.....	6,276	.....	6,119	.....	5,843	5,447

Capacity, in Cubic Feet, of 4" Pipe Line 7 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	194	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	363	317	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	525	485	367	259	.....	.....	.....	.....	.....	.....	.....	.....
40	664	635	549	490	409	.....	.....	.....	.....	.....	.....	.....
50	801	778	710	664	608	448	.....	.....	.....	.....	.....	.....
60	937	917	859	822	778	661	485	.....	.....	.....	.....	.....
70	1,071	.....	1,005	.....	935	840	709	.....	.....	.....	.....	.....
80	1,203	.....	1,145	.....	1,085	1,005	897	.....	.....	.....	.....	.....
90	1,337	.....	1,284	.....	1,230	1,159	1,070	700	.....	.....	.....	.....
100	1,469	.....	1,420	.....	1,368	1,297	1,230	928	.....	.....	.....	.....
125	1,797	.....	.....	1,740	.....	1,669	1,608	1,390	1,035	.....	.....	.....
150	2,124	.....	.....	2,076	.....	2,018	1,967	1,793	1,534	1,387	.....	.....
175	2,450	.....	.....	2,408	.....	.....	2,315	2,170	1,958	1,665	1,221	.....
200	2,777	.....	.....	2,740	.....	.....	2,657	2,533	2,356	2,116	1,788	.....
225	3,101	.....	.....	3,061	.....	.....	2,996	.....	2,723	2,528	2,256	1,374
250	3,426	.....	.....	3,398	.....	.....	3,332	.....	3,097	2,918	2,690	2,009
275	3,752	.....	.....	3,725	.....	.....	3,665	.....	3,452	.....	3,095	2,524
300	4,078	.....	.....	4,053	.....	.....	3,997	.....	3,804	.....	3,480	2,985
325	4,402	.....	.....	4,379	.....	.....	4,328	.....	4,150	.....	3,856	3,416
350	4,727	.....	.....	4,705	.....	.....	4,659	.....	4,493	.....	4,223	3,826
375	5.052	.....	.....	5,031	.....	.....	4,988	.....	4,834	.....	4,583	4,220
400	5,376	.....	.....	5,358	.....	.....	5,305	.....	5,172	.....	4,939	4,604

Capacity, in Cubic Feet, of 4″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	163	....	....	....	....	....	....	....	....	....	....	....
20	304	266	....	....	....	....	....	....	....	....	....	....
30	410	406	307	217	....	....	....	....	....	....	....	....
40	556	533	461	411	343	....	....	....	....	....	....	....
50	672	652	596	556	510	376	....	....	....	....	....	....
60	786	769	721	689	652	554	406	....	....	....	....	....
70	898	....	843	....	784	704	595	....	....	....	....	....
80	1,009	....	960	....	910	843	752	....	....	....	....	....
90	1,121	....	1,076	....	1,032	972	897	587	....	....	....	....
100	1,232	....	1,191	....	1,147	1,087	1,032	778	....	....	....	....
125	1,507	....	....	1,459	....	1,399	1,348	1,166	868	....	....	....
150	1,781	....	....	1,741	....	1,692	1,650	1,504	1,286	1,163	....	....
175	2,054	....	....	2,020	....	....	1,941	1,819	1,642	1,396	1,024	....
200	2,238	....	....	2,298	....	....	2,228	2,124	1,976	1,775	1,500	....
225	2,600	....	....	2,566	....	....	2,512	....	2,284	2,119	1,892	1,152
250	2,873	....	....	2,850	....	....	2,794	....	2,597	....	2,256	1,685
275	3,147	....	....	3,124	....	....	3,074	....	2,895	....	2,594	2,116
300	3,420	....	....	3,399	....	....	3,352	....	3,190	....	2,918	2,504
325	3,691	....	....	3,672	....	....	3,629	....	3,480	....	3,234	2,865
350	3,965	....	....	3,946	....	....	3,907	....	3,768	....	3,541	3,209
375	4,236	....	....	4,219	....	....	4,183	....	4,054	....	3,844	3,539
400	4,508	....	....	4,502	....	....	4,449	....	4,338	....	4,142	3,861

Capacity, in Cubic Feet, of 4″ Pipe Line 15 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	133	....	....	....	....	....	....	....	....	....	....	....
20	248	217	....	....	....	....	....	....	....	....	....	....
30	359	332	251	177	....	....	....	....	....	....	....	....
40	454	435	376	335	280	....	....	....	....	....	....	....
50	548	532	486	454	416	307	....	....	....	....	....	....
60	642	628	588	563	532	453	332	....	....	....	....	....
70	733	....	688	....	640	575	485	....	....	....	....	....
80	824	....	784	....	743	688	614	....	....	....	....	....
90	915	....	879	....	842	794	732	479	....	....	....	....
100	1,006	....	972	....	937	883	842	636	....	....	....	....
125	1,231	....	....	1,192	....	1,143	1,101	952	....	....	....	....
150	1,455	....	....	1,422	....	1,382	1,347	1,228	1,050	950	....	....
175	1,677	....	....	1,649	....	....	1,585	1,486	1,341	1,140	836	....
200	1,901	....	....	1,876	....	....	1,820	1,734	1,614	1,449	1,224	....
225	2,123	....	....	2,076	....	....	2,051	....	1,865	1,731	1,545	941
250	2,346	....	....	2,327	....	....	2,282	....	2,121	....	1,842	1,375
275	2,569	....	....	2,551	....	....	2,510	....	2,364	....	2,118	1,728
300	2,792	....	....	2,775	....	....	2,737	....	2,605	....	2,383	2,044
325	3,014	....	....	2,998	....	....	2,964	....	2,842	....	2,640	2,339
350	3,237	....	....	3,222	....	....	3,190	....	3,061	....	2,892	2,620
375	3,459	....	....	3,445	....	....	3,416	....	3,310	....	3,139	2,890
400	3,682	....	....	3,676	....	....	3,633	....	3,542	....	3,382	3,153

Capacity, in Cubic Feet, of 4" Pipe Line 25 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	103	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	192	168	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	278	257	194	137	.....	.....	.....	.....	.....	.....	.....	.....
40	351	336	291	259	217	.....	.....	.....	.....	.....	.....	.....
50	424	412	376	351	322	237	.....	.....	.....	.....	.....	.....
60	496	485	455	435	412	350	257	.....	.....	.....	.....	.....
70	567	.....	532	.....	494	445	376	.....	.....	.....	.....	.....
80	637	.....	606	.....	575	532	475	.....	.....	.....	.....	.....
90	708	.....	680	.....	652	614	567	371	.....	.....	.....	.....
100	778	.....	752	741	725	687	652	492	.....	.....	.....	.....
125	952	.....	.....	922	.....	884	852	736	548	.....	.....	.....
150	1,125	.....	.....	1,100	.....	1,069	1,042	950	813	735	.....	.....
175	1,298	.....	.....	1,276	.....	.....	1,227	1,150	1,037	882	647	.....
200	1,471	.....	.....	1,452	.....	.....	1,408	1,342	1,249	1,121	917	.....
225	1,643	.....	.....	1,622	.....	.....	1,587	.....	1,443	1,339	1,196	728
250	1,816	.....	.....	1,800	.....	.....	1,765	.....	1,641	1,546	1,425	1,064
275	1,988	.....	.....	1,974	.....	.....	1,942	.....	1,829	.....	1,639	1,337
300	2,161	.....	.....	2,148	.....	.....	2,118	.....	2,016	.....	1,844	1,582
325	2,333	.....	.....	2,320	.....	.....	2,293	.....	2,199	.....	2,043	1,810
350	2,505	.....	.....	2,493	.....	.....	2,469	.....	2,381	.....	2,238	2,027
375	2,677	.....	.....	2,666	.....	.....	2,643	.....	2,561	.....	2,429	2,236
400	2,849	.....	.....	2,839	.....	.....	2,811	.....	2,741	.....	2,617	2,440

Capacity, in Cubic Feet, of 4" Pipe Line 35 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	87	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	162	142	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	235	217	164	116	.....	.....	.....	.....	.....	.....	.....	.....
40	297	284	246	219	183	.....	.....	.....	.....	.....	.....	.....
50	358	348	318	297	272	200	.....	.....	.....	.....	.....	.....
60	419	410	385	368	348	296	217	.....	.....	.....	.....	.....
70	479	.....	450	.....	418	376	317	.....	.....	.....	.....	.....
80	538	.....	512	.....	486	450	401	.....	.....	.....	.....	.....
90	598	.....	574	.....	551	519	479	.....	.....	.....	.....	.....
100	657	.....	635	625	612	580	551	415	.....	.....	.....	.....
125	804	.....	.....	779	.....	747	720	622	463	.....	.....	.....
150	951	.....	.....	929	.....	903	880	803	686	621	.....	.....
175	1,096	.....	.....	1,078	.....	.....	1,036	971	876	745	547	.....
200	1,243	.....	.....	1,227	.....	.....	1,189	1,134	1,055	947	800	.....
225	1,388	.....	.....	1,370	.....	.....	1,341	.....	1,219	1,131	1,010	615
250	1,534	.....	.....	1,521	.....	.....	1,491	.....	1,386	1,306	1,204	899
275	1,679	.....	.....	1,667	.....	.....	1,641	.....	1,545	.....	1,384	1,130
300	1,825	.....	.....	1,814	.....	.....	1,789	.....	1,703	.....	1,558	1,336
325	1,970	.....	.....	1,960	.....	.....	1,937	.....	1,858	.....	1,726	1,529
350	2,116	.....	.....	2,106	.....	.....	2,085	.....	2,011	.....	1,890	1,713
375	2,261	.....	.....	2,252	.....	.....	2,233	.....	2,164	.....	2,052	1,889
400	2,407	.....	.....	2,398	.....	.....	2,375	.....	2,315	.....	2,211	2,061

Capacity, in Cubic Feet, of 4″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	72	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	136	119	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	196	181	137	97	.....	.....	.....	.....	.....	.....	.....	.....
40	248	238	206	183	153	.....	.....	.....	.....	.....	.....	.....
50	300	291	266	248	228	168	.....	.....	.....	.....	.....	.....
60	351	343	322	308	291	247	181	.....	.....	.....	.....	.....
70	401	.....	376	.....	350	315	265	.....	.....	.....	.....	.....
80	451	.....	429	.....	406	376	336	.....	.....	.....	.....	.....
90	501	.....	481	.....	461	434	401	262	.....	.....	.....	.....
100	550	.....	532	.....	512	486	461	348	.....	.....	.....	.....
125	673	.....	.....	652	.....	625	602	521	387	.....	.....	.....
150	796	.....	.....	778	.....	756	737	672	575	520	.....	.....
175	918	.....	.....	902	.....	.....	867	813	734	624	458	.....
200	1,040	.....	.....	1,027	.....	.....	996	949	883	793	670	.....
225	1,162	.....	.....	1,147	.....	.....	1,123	.....	1,021	947	845	515
250	1,284	.....	.....	1,273	.....	.....	1,249	.....	1,161	1,093	1,008	753
275	1,406	.....	.....	1,396	.....	.....	1,374	.....	1,294	.....	1,159	946
300	1,528	.....	.....	1,519	.....	.....	1,498	.....	1,426	.....	1,304	1,119
325	1,650	.....	.....	1,641	.....	.....	1,622	.....	1,555	.....	1,445	1,280
350	1,772	.....	.....	1,763	.....	.....	1,746	.....	1,684	.....	1,583	1,434
375	1,893	.....	.....	1,885	.....	.....	1,869	.....	1,812	.....	1,718	1,582
400	2,015	.....	.....	2,008	.....	.....	1,988	.....	1,938	.....	1,851	1,726

Capacity, in Cubic Feet, of 4″ Pipe Line 70 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	114	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	166	153	116	82	.....	.....	.....	.....	.....	.....	.....	.....
40	210	201	174	155	129	.....	.....	.....	.....	.....	.....	.....
50	253	246	224	210	192	142	.....	.....	.....	.....	.....	.....
60	296	290	272	260	246	209	153	.....	.....	.....	.....	.....
70	339	.....	318	.....	295	266	224	.....	.....	.....	.....	.....
80	380	.....	362	.....	343	318	284	.....	.....	.....	.....	.....
90	423	.....	406	.....	389	366	338	221	.....	.....	.....	.....
100	465	.....	449	442	433	410	389	293	.....	.....	.....	.....
125	568	.....	.....	550	.....	528	509	440	327	.....	.....	.....
150	672	.....	.....	657	.....	638	622	567	485	439	.....	.....
175	775	.....	.....	762	.....	.....	732	686	619	527	386	.....
200	878	.....	.....	867	.....	.....	841	801	745	669	566	.....
225	981	.....	.....	968	.....	.....	948	.....	862	800	714	435
250	1,084	.....	.....	1,075	.....	.....	1,054	.....	980	923	851	635
275	1,187	.....	.....	1,178	.....	.....	1,160	.....	1,092	.....	979	798
300	1,290	.....	.....	1,282	.....	.....	1,265	.....	1,203	.....	1,101	944
325	1,393	.....	.....	1,385	.....	.....	1,369	.....	1,313	.....	1,220	1,081
350	1,496	.....	.....	1,489	.....	.....	1,474	.....	1,421	.....	1,336	1,210
375	1,598	.....	.....	1,592	.....	.....	1,578	.....	1,529	.....	1,450	1,335
400	1,701	.....	.....	1,695	.....	.....	1,678	.....	1,637	.....	1,563	1,457

Capacity, in Cubic Feet, of 4″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	51	....	....	....	....	....	....	....	....	....	....	....
20	96	84	....	....	....	....	....	....	....	....	....	....
30	139	128	97	68	....	....	....	....	....	....	....	....
40	175	168	145	129	108	....	....	....	....	....	....	....
50	212	206	188	175	161	118	....	....	....	....	....	....
60	248	242	227	217	206	175	128	....	....	....	....	....
70	283	....	266	....	247	222	188	....	....	....	....	....
80	318	....	303	....	287	266	237	....	....	....	....	....
90	354	....	340	....	326	307	283	185	....	....	....	....
100	389	....	376	....	362	343	326	246	....	....	....	....
125	476	....	....	461	....	442	426	368	274	....	....	....
150	562	....	....	550	....	534	521	475	406	367	....	....
175	649	....	....	638	....	....	613	575	518	441	323	....
200	735	....	....	726	....	....	704	671	624	560	473	....
225	821	....	....	811	....	....	793	....	721	669	598	364
250	908	....	....	900	....	....	882	....	820	773	712	532
275	994	....	....	987	....	....	971	....	914	....	819	668
300	1,080	....	....	1,074	....	....	1,059	....	1,008	....	922	791
325	1,166	....	....	1,160	....	....	1,146	....	1,099	....	1,021	905
350	1,252	....	....	1,246	....	....	1,234	....	1,190	....	1,119	1,013
375	1,338	....	....	1,333	....	....	1,321	....	1,280	....	1,214	1,118
400	1,424	....	....	1,419	....	....	1,405	....	1,370	....	1,308	1,220

Capacity, in Cubic Feet, of 6″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,436	....	....	....	....	....	....	....	....	....	....	....
20	2,681	2,346	....	....	....	....	....	....	....	....	....	....
30	3,878	3,581	2,710	1,915	....	....	....	....	....	....	....	....
40	4,902	4,692	4,060	3,619	3,026	....	....	....	....	....	....	....
50	5,917	5,745	5,247	4,902	4,491	3,313	....	....	....	....	....	....
60	6,923	6,770	6,348	....	5,745	4,883	3,581	....	....	....	....	....
70	7,900	....	7,421	....	6,904	6,205	5,238	....	....	....	....	....
80	8,886	....	8,455	....	8,015	7,421	6,626	....	....	....	....	....
90	9,872	....	9,480	....	9,087	8,560	7,900	5,171	....	....	....	....
100	10,849	....	10,485	....	10,102	9,576	9,087	6,856	....	....	....	....
125	13,272	....	....	12,850	....	12,324	11,874	10,265	7,641	....	....	....
150	15,685	....	....	15,331	....	14,900	14,526	13,243	11,328	10,246	....	....
175	18,089	....	....	17,782	....	....	17,093	16,020	14,459	12,295	9,020	....
200	20,502	....	....	20,234	....	....	19,621	18,701	17,399	15,628	13,205	....
225	22,896	....	....	22,599	....	....	22,120	....	20,109	18,663	16,662	10,150
250	25,299	....	....	25,089	....	....	24,600	....	22,867	21,546	19,860	14,833
275	27,703	....	....	27,502	....	....	27,061	....	25,491	....	22,838	18,634
300	30,106	....	....	29,925	....	....	29,513	....	28,086	....	25,692	22,043
325	32,500	....	....	32,328	....	....	31,955	....	30,643	....	28,469	25,223
350	34,904	....	....	34,741	....	....	34,396	....	33,171	....	31,179	28,249
375	37,298	....	....	37,145	....	....	36,829	....	35,689	....	33,841	31,160
400	39,692	....	....	39,558	....	....	39,165	....	38,189	....	36,465	33,994

Capacity, in Cubic Feet, of 6″ Pipe Line 2 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,018	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,901	1,663	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,750	2,540	1,921	1,358	.....	.....	.....	.....	.....	.....	.....	.....
40	3,477	3,327	2,879	2,567	2,146	.....	.....	.....	.....	.....	.....	.....
50	4,197	4,074	3,721	3,477	3,185	2,349	.....	.....	.....	.....	.....	.....
60	4,910	4,801	4,502	.....	4,074	3,463	2,540	.....	.....	.....	.....	.....
70	5,609	.....	5,263	.....	4,896	4,400	3,714	.....	.....	.....	.....	.....
80	6,302	.....	5,696	.....	5,684	5,263	4,699	.....	.....	.....	.....	.....
90	7,002	.....	6,723	.....	6,445	6,071	5,602	3,667	.....	.....	.....	.....
100	7,694	.....	7,436	.....	7,165	6,791	6,445	4,862	.....	.....	.....	.....
125	9,413	.....	.....	9,114	.....	8,740	8,421	7,280	5,419	.....	.....	.....
150	11,124	.....	.....	10,873	.....	10,567	10,302	9,392	8,034	7,266	.....	.....
175	12,829	.....	.....	12,611	.....	.....	12,122	11,362	10,255	8,720	6,397	.....
200	14,540	.....	.....	14,350	.....	.....	13,915	13,263	12,340	11,083	9,365	.....
225	16,238	.....	.....	16,027	.....	.....	15,688	.....	14,262	13,236	11,817	7,198
250	17,943	.....	.....	17,793	.....	.....	17,447	.....	16,218	15,280	14,085	10,520
275	19,647	.....	.....	19,505	.....	.....	19,192	.....	18,078	.....	16,197	13,216
300	21,352	.....	.....	21,223	.....	.....	20,931	.....	19,919	.....	18,221	15,634
325	23,050	.....	.....	22,928	.....	.....	22,663	.....	21,732	.....	20,191	17,888
350	24,755	.....	.....	24,639	.....	.....	24,395	.....	23,525	.....	22,113	20,034
375	26,452	.....	.....	26,344	.....	.....	26,120	.....	25,311	.....	24,001	22,099
400	28,150	.....	.....	28,055	.....	.....	27,777	.....	27,084	.....	25,862	24,109

Capacity, in Cubic Feet, of 6″ Pipe Line 3 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	830	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,549	1,356	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,241	2,070	1,566	1,107	.....	.....	.....	.....	.....	.....	.....	.....
40	2,834	2,712	2,347	2,092	1,749	.....	.....	.....	.....	.....	.....	.....
50	3,421	3,321	3,033	2,834	2,596	1,915	.....	.....	.....	.....	.....	.....
60	4,002	3,913	3,670	.....	3,321	2,823	2,070	.....	.....	.....	.....	.....
70	4,572	.....	4,290	.....	3,991	3,587	3,027	.....	.....	.....	.....	.....
80	5,137	.....	4,887	.....	4,633	4,290	3,830	.....	.....	.....	.....	.....
90	5,707	.....	5,480	.....	5,253	4,948	4,566	2,989	.....	.....	.....	.....
100	6,271	.....	6,061	.....	5,840	5,535	5,253	3,963	.....	.....	.....	.....
125	7,672	.....	.....	7,428	.....	7,124	6,864	5,934	4,417	.....	.....	.....
150	9,067	.....	.....	8,862	.....	8,613	8,397	7,655	6,548	5,923	.....	.....
175	10,456	.....	.....	10,279	.....	.....	9,881	9,261	8,358	7,107	5,214	.....
200	11,851	.....	.....	11,696	.....	.....	11,342	10,811	10,058	9,034	7,633	.....
225	13,235	.....	.....	13,064	.....	.....	12,787	.....	11,624	10,788	9,631	5,867
250	14,625	.....	.....	14,503	.....	.....	14,220	.....	13,219	12,455	11,480	8,574
275	16,014	.....	.....	15,898	.....	.....	15,643	.....	14,735	.....	13,202	10,772
300	17,403	.....	.....	17,298	.....	.....	17,060	.....	16,235	.....	14,852	12,742
325	18,787	.....	.....	18,688	.....	.....	18,472	.....	17,713	.....	16,457	14,580
350	20,177	.....	.....	20,083	.....	.....	19,883	.....	19,175	.....	18,023	16,330
375	21,561	.....	.....	21,472	.....	.....	21,289	.....	20,631	.....	19,562	18,012
400	22,945	.....	.....	22,867	.....	.....	22,640	.....	22,075	.....	21,079	19,651

Capacity, in Cubic Feet, of 6″ Pipe Line 4 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	718	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,340	1,173	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,939	1,790	1,355	957	.....	.....	.....	.....	.....	.....	.....	.....
40	2,451	2,346	2,030	1,809	1,513	.....	.....	.....	.....	.....	.....	.....
50	2,958	2,872	2,623	2,451	2,245	1,656	.....	.....	.....	.....	.....	.....
60	3,461	3,385	3,174	.....	2,872	2,441	1,790	.....	.....	.....	.....	.....
70	3,954	.....	3,710	.....	3,452	3,102	2,619	.....	.....	.....	.....	.....
80	4,443	.....	4,227	.....	4,007	3,710	3,313	.....	.....	.....	.....	.....
90	4,936	.....	4,740	.....	4,543	4,280	3,950	2,585	.....	.....	.....	.....
100	5,424	.....	5,242	.....	5,051	4,788	4,543	3,428	.....	.....	.....	.....
125	6,636	.....	.....	6,425	.....	6,162	5,937	5,132	3,820	.....	.....	.....
150	7,842	.....	.....	7,665	.....	7,450	7,263	6,621	5,664	5,123	.....	.....
175	9,044	.....	.....	8,891	.....	.....	8,546	8,010	7,229	6,147	4,510	.....
200	10,251	.....	.....	10,117	.....	.....	9,810	9,350	8,699	7,814	6,602	.....
225	11,448	.....	.....	11,299	.....	.....	11,060	.....	10,054	9,331	8,331	5,075
250	12,649	.....	.....	12,544	.....	.....	12,300	.....	11,433	10,773	9,930	7,416
275	13,851	.....	.....	13,751	.....	.....	13,530	.....	12,745	.....	11,419	9,317
300	15,053	.....	.....	14,962	.....	.....	14,756	.....	14,043	.....	12,846	11,021
325	16,250	.....	.....	16,164	.....	.....	15,977	.....	15,321	.....	14,234	12,611
350	17,452	.....	.....	17,370	.....	.....	17,198	.....	16,585	.....	15,589	14,124
375	18,649	.....	.....	18,572	.....	.....	18,414	.....	17,844	.....	16,920	15,580
400	19,846	.....	.....	19,779	.....	.....	19,582	.....	19,094	.....	18,232	16,997

Capacity, in Cubic Feet, of 6″ Pipe Line 5 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	641	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,197	1,047	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,731	1,598	1,209	855	.....	.....	.....	.....	.....	.....	.....	.....
40	2,188	2,098	1,812	1,615	1,350	.....	.....	.....	.....	.....	.....	.....
50	2,641	2,565	2,342	2,188	2,004	1,479	.....	.....	.....	.....	.....	.....
60	3,090	3,022	2,834	2,710	2,565	2,180	1,598	.....	.....	.....	.....	.....
70	3,531	.....	3,313	.....	3,082	2,770	2,338	.....	.....	.....	.....	.....
80	3,967	.....	3,774	.....	3,578	3,313	2,958	.....	.....	.....	.....	.....
90	4,407	.....	4,232	.....	4,056	3,821	3,526	2,308	.....	.....	.....	.....
100	4,843	.....	4,681	4,608	4,510	4,275	4,056	3,060	.....	.....	.....	.....
125	5,925	.....	.....	5,737	.....	5,501	5,301	4,582	3,411	.....	.....	.....
150	7,002	.....	.....	6,844	.....	6,651	6,485	5,912	5,057	4,574	.....	.....
175	8,075	.....	.....	7,938	.....	.....	7,630	7,152	6,455	5,489	4,027	.....
200	9,152	.....	.....	9,033	.....	.....	8,759	8,349	7,767	6,976	5,895	.....
225	10,221	.....	.....	10,089	.....	.....	9,875	.....	8,977	8,331	7,438	4,531
250	11,294	.....	.....	11,200	.....	.....	10,982	.....	10,208	9,618	8,866	6,621
275	12,367	.....	.....	12,277	.....	.....	12,081	.....	11,380	.....	10,195	8,319
300	13,440	.....	.....	13,359	.....	.....	13,175	.....	12,538	.....	11,469	9,841
325	14,509	.....	.....	14,432	.....	.....	14,265	.....	13,680	.....	12,709	11,260
350	15,582	.....	.....	15,509	.....	.....	15,355	.....	14,808	.....	13,919	12,611
375	16,651	.....	.....	16,582	.....	.....	16,441	.....	15,932	.....	15,107	13,910
400	17,719	.....	.....	17,660	.....	.....	17,484	.....	17,048	.....	16,279	15,176

Capacity, in Cubic Feet, of 6″ Pipe Line 7 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	542	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,011	885	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,463	1,351	1,022	722	.....	.....	.....	.....	.....	.....	.....	.....
40	1,850	1,770	1,532	1,366	1,141	.....	.....	.....	.....	.....	.....	.....
50	2,233	2,168	1,980	1,850	1,694	1,250	.....	.....	.....	.....	.....	.....
60	2,612	2,554	2,395	.....	2,168	1,843	1,351	.....	.....	.....	.....	.....
70	2,984	.....	2,800	.....	2,605	2,341	1,976	.....	.....	.....	.....	.....
80	3,353	.....	3,190	.....	3,024	2,800	2,500	.....	.....	.....	.....	.....
90	3,725	.....	3,577	.....	3,429	3,230	2,981	1,951	.....	.....	.....	.....
100	4,094	.....	3,957	.....	3,812	3,613	3,429	2,587	.....	.....	.....	.....
125	5,008	.....	.....	4,849	.....	4,509	4,481	3,873	2,883	.....	.....	.....
150	5,919	.....	.....	5,785	.....	5,623	5,482	4,997	4,275	3,866	.....	.....
175	6,826	.....	.....	6,710	.....	.....	6,450	6,045	5,456	4,640	3,404	.....
200	7,737	.....	.....	7,635	.....	.....	7,404	7,057	6,566	5,897	4,983	.....
225	8,640	.....	.....	8,528	.....	.....	8,347	.....	7,588	7,043	6,288	3,830
250	9,547	.....	.....	9,468	.....	.....	9,283	.....	8,629	8,131	7,495	5,597
275	10,454	.....	.....	10,378	.....	.....	10,212	.....	9,619	.....	8,618	7,032
300	11,361	.....	.....	11,293	.....	.....	11,137	.....	10,599	.....	9,695	8,318
325	12,265	.....	.....	12,200	.....	.....	12,059	.....	11,564	.....	10,743	9,518
350	13,172	.....	.....	13,110	.....	.....	12,980	.....	12,518	.....	11,766	10,660
375	14,075	.....	.....	14,017	.....	.....	13,898	.....	13,468	.....	12,771	11,759
400	14,979	.....	.....	14,928	.....	.....	14,780	.....	14,411	.....	13,761	12,828

Capacity, in Cubic Feet, of 6″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	454	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	848	742	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,227	1,133	857	606	.....	.....	.....	.....	.....	.....	.....	.....
40	1,551	1,484	1,284	1,145	957	.....	.....	.....	.....	.....	.....	.....
50	1,872	1,818	1,660	1,551	1,421	1,048	.....	.....	.....	.....	.....	.....
60	2,191	2,142	2,009	1,921	1,818	1,545	1,133	.....	.....	.....	.....	.....
70	2,503	.....	2,348	.....	2,184	1,963	1,657	.....	.....	.....	.....	.....
80	2,812	.....	2,675	.....	2,536	2,348	2,097	.....	.....	.....	.....	.....
90	3,124	.....	3,000	.....	2,875	2,709	2,500	1,636	.....	.....	.....	.....
100	3,427	.....	3,318	3,266	3,197	3,030	2,875	2,169	.....	.....	.....	.....
125	4,200	.....	.....	4,066	.....	3,900	3,751	3,248	2,418	.....	.....	.....
150	4,963	.....	.....	4,851	.....	4,715	4,597	4,191	3,585	3,242	.....	.....
175	5,724	.....	.....	5,627	.....	.....	5,409	5,070	4,576	3,891	2,854	.....
200	6,488	.....	.....	6,403	.....	.....	6,209	5,918	5,506	4,945	4,179	.....
225	7,245	.....	.....	7,151	.....	.....	7,000	.....	6,364	5,906	5,273	3,212
250	8,006	.....	.....	7,939	.....	.....	7,785	.....	7,236	6,818	6,285	4,694
275	8,767	.....	.....	8,703	.....	.....	8,564	.....	8,067	.....	7,227	5,897
300	9,527	.....	.....	9,470	.....	.....	9,340	.....	8,888	.....	8,130	6,976
325	10,285	.....	.....	10,230	.....	.....	10,112	.....	9,697	.....	9,009	7,982
350	11,046	.....	.....	10,994	.....	.....	10,885	.....	10,497	.....	9,867	8,939
375	11,803	.....	.....	11,755	.....	.....	11,655	.....	11,294	.....	10,709	9,861
400	12,561	.....	.....	12,518	.....	.....	12,394	.....	12,085	.....	11,540	10,758

Capacity, in Cubic Feet, of 6″ Pipe Line 15 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	371	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	692	606	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,002	925	700	494	.....	.....	.....	.....	.....	.....	.....	.....
40	1,267	1,212	1,049	935	782	.....	.....	.....	.....	.....	.....	.....
50	1,529	1,484	1,356	1,267	1,160	856	.....	.....	.....	.....	.....	.....
60	1,789	1,749	1,640	1,568	1,484	1,262	925	.....	.....	.....	.....	.....
70	2,044	.....	1,917	.....	1,784	1,603	1,353	.....	.....	.....	.....	.....
80	2,296	.....	2,185	.....	2,071	1,917	1,712	.....	.....	.....	.....	.....
90	2,551	.....	2,449	.....	2,348	2,212	2,041	1,336	.....	.....	.....	.....
100	2,803	.....	2,709	2,667	2,610	2,474	2,348	1,771	.....	.....	.....	.....
125	3,429	.....	.....	3,321	.....	3,184	3,068	2,652	1,974	.....	.....	.....
150	4,053	.....	.....	3,961	.....	3,850	3,754	3,422	2,927	2,647	.....	.....
175	4,674	.....	.....	4,595	.....	.....	4,417	4,140	3,736	3,177	2,331	.....
200	5,298	.....	.....	5,229	.....	.....	5,070	4,833	4,496	4,038	3,412	.....
225	5,917	.....	.....	5,840	.....	.....	5,716	.....	5,196	4,823	4,305	2,623
250	6,538	.....	.....	6,483	.....	.....	6,357	.....	5,909	5,568	5,132	3,833
275	7,159	.....	.....	7,107	.....	.....	6,993	.....	6,587	.....	5,902	4,815
300	7,780	.....	.....	7,733	.....	.....	7,627	.....	7,258	.....	6,639	5,696
325	8,399	.....	.....	8,354	.....	.....	8,258	.....	7,919	.....	7,357	6,518
350	9,020	.....	.....	8,978	.....	.....	8,889	.....	8,572	.....	8,057	7,300
375	9,638	.....	.....	9,599	.....	.....	9,517	.....	9,223	.....	8,745	8,052
400	10,257	.....	.....	10,222	.....	.....	10,121	.....	9,869	.....	9,423	[illegible],785

Capacity, in Cubic Feet, of 6″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	321	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	599	524	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	867	801	606	428	.....	.....	.....	.....	.....	.....	.....	.....
40	1,096	1,049	908	809	676	.....	.....	.....	.....	.....	.....	.....
50	1,323	1,285	1,173	1,096	1,004	741	.....	.....	.....	.....	.....	.....
60	1,548	1,514	1,420	1,358	1,285	1,092	801	.....	.....	.....	.....	.....
70	1,769	.....	1,660	.....	1,544	1,388	1,171	.....	.....	.....	.....	.....
80	1,987	.....	1,891	.....	1,793	1,660	1,482	.....	.....	.....	.....	.....
90	2,208	.....	2,120	.....	2,032	1,915	1,767	1,156	.....	.....	.....	.....
100	2,427	.....	2,345	2,309	2,260	2,142	2,032	1,533	.....	.....	.....	.....
125	2,969	.....	.....	2,874	.....	2,757	2,656	2,296	1,709	.....	.....	.....
150	3,508	.....	.....	3,429	.....	3,333	3,249	2,962	2,534	2,292	.....	.....
175	4,046	.....	.....	3,978	.....	.....	3,823	3,583	3,234	2,750	2,017	.....
200	4,586	.....	.....	4,526	.....	.....	4,389	4,183	3.892	3,496	2,954	.....
225	5,122	.....	.....	5,055	.....	.....	4,948	.....	4,498	4,175	3,727	2,270
250	5,659	.....	.....	5,612	.....	.....	5,503	.....	5,115	4,819	4,442	3,318
275	6,197	.....	.....	6,152	.....	.....	6,053	.....	5,702	.....	5,109	4,168
300	6,735	.....	.....	6,694	.....	.....	6,602	.....	6,283	.....	5,747	4,931
325	7,270	.....	.....	7,232	.....	.....	7,148	.....	6,855	.....	6,368	5,642
350	7,808	.....	.....	7,771	.....	.....	7,694	.....	7,420	.....	6,975	6,319
375	8,343	.....	.....	8,309	.....	.....	8,238	.....	7,983	.....	7,570	6,970
400	8,879	.....	.....	8,849	.....	.....	8,761	.....	8,543	.....	8,157	7,604

Capacity, in Cubic Feet, of 6″ Pipe Line 30 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	262	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	489	428	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	707	653	494	349	.....	.....	.....	.....	.....	.....	.....	.....
40	894	856	740	660	552	.....	.....	.....	.....	.....	.....	.....
50	1,079	1,048	957	894	819	604	.....	.....	.....	.....	.....	.....
60	1,263	1,235	1,158	1,107	1,048	890	653	.....	.....	.....	.....	.....
70	1,443	.....	1,353	.....	1,259	1,132	955	.....	.....	.....	.....	.....
80	1,621	.....	1,542	.....	1,462	1,353	1,208	.....	.....	.....	.....	.....
90	1,801	.....	1,729	.....	1,657	1,561	1,441	943	.....	.....	.....	.....
100	1,979	.....	1,912	1,883	1,843	1,747	1,657	1,250	.....	.....	.....	.....
125	2,421	.....	.....	2,344	.....	2,248	2,166	1,872	1,394	.....	.....	.....
150	2,861	.....	.....	2,796	.....	2,718	2,650	2,416	2,066	1,869	.....	.....
175	3,300	.....	.....	3,244	.....	.....	3,118	2,922	2,637	2,243	1,645	.....
200	3,740	.....	.....	3,691	.....	.....	3,579	·3,411	3,174	2,851	2,409	.....
225	4,177	.....	.....	4,122	.....	.....	4,035	.....	3,668	3,404	3,039	1,851
250	4,615	.....	.....	4,577	.....	.....	4,488	.....	4,171	3,930	3,623	2,706
275	5,054	.....	.....	5,017	.....	.....	4,937	.....	4,650	.....	4,166	3,399
300	5,492	.....	.....	5,459	.....	.....	5,384	.....	5,123	.....	4,687	4,021
325	5,929	.....	.....	5,897	.....	.....	5,829	.....	5,590	.....	5,193	4,601
350	6,367	.....	.....	6,338	.....	.....	6,275	.....	6,051	.....	5,688	5,153
375	6,804	.....	.....	6,776	.....	.....	6,718	.....	6,511	.....	6,173	5,684
400	7,241	.....	.....	7,216	.....	.....	7,145	.....	6,967	.....	6,652	6,201

Capacity, in Cubic Feet, of 6″ Pipe Line 40 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	227	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	424	371	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	613	566	428	303	.....	.....	.....	.....	.....	.....	.....	.....
40	775	742	642	572	478	.....	.....	.....	.....	.....	.....	.....
50	936	909	830	775	710	524	.....	.....	.....	.....	.....	.....
60	1,095	1,071	1,004	.....	909	772	566	.....	.....	.....	.....	.....
70	1,251	.....	1,174	.....	1,092	981	828	.....	.....	.....	.....	.....
80	1,406	.....	1,337	.....	1,268	1,174	1,048	.....	.....	.....	.....	.....
90	1,562	.....	1,500	.....	1,437	1,354	1,250	818	.....	.....	.....	.....
100	1,716	.....	1,659	.....	1,598	1,515	1,437	1,084	.....	.....	.....	.....
125	2,100	.....	.....	2,033	.....	1,950	1,878	1,624	1,209	.....	.....	.....
150	2,481	.....	.....	2,425	.....	2,357	2,298	2,095	1,792	1,621	.....	.....
175	2,862	.....	.....	2,813	.....	.....	2,704	2,534	2,287	1,945	1,427	.....
200	3,244	.....	.....	3,201	.....	.....	3,104	2,959	2,753	2,472	2,089	.....
225	3,622	.....	.....	3,575	.....	.....	3,506	.....	3,181	2,953	2,636	1,606
250	4,003	.....	.....	3,969	.....	.....	3,892	.....	3,618	3,409	3,142	2,347
275	4,383	.....	.....	4,351	.....	.....	4,281	.....	4,033	.....	3,613	2,948
300	4,763	.....	.....	4,735	.....	.....	4,669	.....	4,444	.....	4,065	3,487
325	5,142	.....	.....	5,115	.....	.....	5,056	.....	4,848	.....	4,504	3,991
350	5,522	.....	.....	5,497	.....	.....	5,442	.....	5,248	.....	4,933	4,469
375	5,901	.....	.....	5,877	.....	.....	5,827	.....	5,647	.....	5,354	4,930
400	6,280	.....	.....	6,259	.....	.....	6,197	.....	6,042	.....	5,769	5,378

Capacity, in Cubic Feet, of 6″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	203	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	379	331	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	548	506	383	270	.....	.....	.....	.....	.....	.....	.....	.....
40	693	663	574	512	428	.....	.....	.....	.....	.....	.....	.....
50	837	812	742	693	635	468	.....	.....	.....	.....	.....	.....
60	979	957	898	858	812	690	506	.....	.....	.....	.....	.....
70	1,118	.....	1,049	.....	976	877	741	.....	.....	.....	.....	.....
80	1,257	.....	1,196	.....	1,133	1,049	937	.....	.....	.....	.....	.....
90	1,396	.....	1,341	.....	1,285	1,211	1,117	731	.....	.....	.....	.....
100	1,534	.....	1,483	1,460	1,429	1,354	1,285	969	.....	.....	.....	.....
125	1,877	.....	.....	1,818	.....	1,743	1,679	1,452	1,083	.....	.....	.....
150	2,218	.....	.....	2,168	.....	2,107	2,055	1,873	1,602	1,449	.....	.....
175	2,559	.....	.....	2,515	.....	.....	2,418	2,266	2,045	1,739	1,276	.....
200	2,900	.....	.....	2,862	.....	.....	2,775	2,645	2,461	2,210	1,868	.....
225	3,239	.....	.....	3,197	.....	.....	3,129	.....	2,844	2,640	2,357	1,435
250	3,579	.....	.....	3,549	.....	.....	3,480	.....	3,235	3,048	2,809	2,098
275	3,919	.....	.....	3,890	.....	.....	3,828	.....	3,606	.....	3,230	2,636
300	4,259	.....	.....	4,233	.....	.....	4,175	.....	3,973	.....	3,634	3,118
325	4,597	.....	.....	4,573	.....	.....	4,520	.....	4,335	.....	4,027	3,568
350	4,937	.....	.....	4,914	.....	.....	4,866	.....	4,692	.....	4,410	3,996
375	5,276	.....	.....	5,254	.....	.....	5,210	.....	5,048	.....	4,787	4,408
400	5,615	.....	.....	5,596	.....	.....	5,540	.....	5,402	.....	5,058	4,809

Capacity, in Cubic Feet, of 6″ Pipe Line 70 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	171	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	320	280	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	463	427	323	228	.....	.....	.....	.....	.....	.....	.....	.....
40	585	560	484	432	361	.....	.....	.....	.....	.....	.....	.....
50	706	686	626	585	536	395	.....	.....	.....	.....	.....	.....
60	826	808	758	.....	686	583	427	.....	.....	.....	.....	.....
70	944	.....	886	.....	824	741	625	.....	.....	.....	.....	.....
80	1,061	.....	1,009	.....	957	886	791	.....	.....	.....	.....	.....
90	1,179	.....	1,132	.....	1,085	1,022	943	617	.....	.....	.....	.....
100	1,295	.....	1,252	.....	1,206	1,143	1,085	818	.....	.....	.....	.....
125	1,585	.....	.....	1,534	.....	1,472	1,418	1,226	912	.....	.....	.....
150	1,873	.....	.....	1,831	.....	1,779	1,735	1,581	1,353	1,223	.....	.....
175	2,160	.....	.....	2,124	.....	.....	2,041	1,913	1,727	1,468	1,077	.....
200	2,448	.....	.....	2,416	.....	.....	2,343	2,233	2,078	1,866	1,577	.....
225	2,734	.....	.....	2,699	.....	.....	2,642	.....	2,401	2,229	1,990	1,212
250	3,021	.....	.....	2,996	.....	.....	2,938	.....	2,731	2,573	2,372	1,771
275	3,309	.....	.....	3,284	.....	.....	3,232	.....	3,044	.....	2,727	2,225
300	3,596	.....	.....	3,574	.....	.....	3,525	.....	3,354	.....	3,068	2,633
325	3,882	.....	.....	3,861	.....	.....	3,816	.....	3,660	.....	3,400	3,012
350	4,169	.....	.....	4,149	.....	.....	4,108	.....	3,962	.....	3,724	3,374
375	4,455	.....	.....	4,436	.....	.....	4,399	.....	4,262	.....	4,042	3,721
400	4,741	.....	.....	4,725	.....	.....	4,678	.....	4,561	.....	4,355	4,060

Capacity, in Cubic Feet, of 6″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	143	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	268	234	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	387	358	271	191	.....	.....	.....	.....	.....	.....	.....	.....
40	490	469	406	361	302	.....	.....	.....	.....	.....	.....	.....
50	591	574	524	490	449	331	.....	.....	.....	.....	.....	.....
60	692	677	634	607	574	488	358	.....	.....	.....	.....	.....
70	790	.....	742	.....	690	620	523	.....	.....	.....	.....	.....
80	888	.....	845	.....	801	742	662	.....	.....	.....	.....	.....
90	987	.....	948	.....	908	856	790	517	.....	.....	.....	.....
100	1,084	.....	1,048	1,032	1,010	957	908	685	.....	.....	.....	.....
125	1,327	.....	.....	1,285	.....	1,237	1,187	1,026	764	.....	.....	.....
150	1,568	.....	.....	1,533	.....	1,490	1,452	1,324	1,132	1,024	.....	.....
175	1,808	.....	.....	1,778	.....	.....	1,709	1,602	1,445	1,229	902	.....
200	2,050	.....	.....	2,023	.....	.....	1,962	1,870	1,739	1,562	1,320	.....
225	2,289	.....	.....	2,259	.....	.....	2,212	.....	2,010	1,866	1,666	1,015
250	2,529	.....	.....	2,508	.....	.....	2,460	.....	2,286	2,154	1,986	1,483
275	2,770	.....	.....	2,750	.....	.....	2,706	.....	2,549	.....	2,283	1,863
300	3,010	.....	.....	2,992	.....	.....	2,951	.....	2,808	.....	2,569	2,204
325	3,250	.....	.....	3,232	.....	.....	3,195	.....	3,064	.....	2,846	2,522
350	3,490	.....	.....	3,474	.....	.....	3,439	.....	3,317	.....	3,117	2,824
375	3,729	.....	.....	3,714	.....	.....	3,682	.....	3,568	.....	3,384	3,116
400	3,969	.....	.....	3,955	.....	.....	3,916	.....	3,818	.....	3,646	3,399

Capacity, in Cubic Feet, of 8″ Pipe Line 1 Mile Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,993	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	5,588	4,889	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	8,083	7,464	5,648	3,991	.....	.....	.....	.....	.....	.....	.....	.....
40	10,218	9,779	8,462	7,544	6,306	.....	.....	.....	.....	.....	.....	.....
50	12,334	11,975	10,937	10,218	9,360	6,905	.....	.....	.....	.....	.....	.....
60	14,429	14,110	13,232	.....	11,975	10,178	7,464	.....	.....	.....	.....	.....
70	16,485	.....	15,467	.....	14,390	12,933	10,917	.....	.....	.....	.....	.....
80	18,521	.....	17,623	.....	16,705	15,467	13,811	.....	.....	.....	.....	.....
90	20,577	.....	19,758	.....	18,940	17,842	16,465	10,777	.....	.....	.....	.....
100	22,612	.....	21,854	.....	21,056	19,958	18,940	14,290	.....	.....	.....	.....
125	27,662	.....	.....	26,784	.....	25,686	24,748	21,395	15,926	.....	.....	.....
150	32,691	.....	.....	31,953	.....	31,055	30,276	27,602	23,610	21,355	.....	.....
175	37,701	.....	.....	37,062	.....	.....	35,625	33,390	30,137	25,626	18,809	.....
200	42,730	.....	.....	42,172	.....	.....	40,894	38,978	36,264	32,572	27,522	.....
225	47,720	.....	.....	47,101	.....	.....	46,103	.....	41,912	38,898	34,727	21,155
250	52,730	.....	.....	52,291	.....	.....	51,273	.....	47,660	44,906	41,393	30,915
275	57,739	.....	.....	57,320	.....	.....	56,402	.....	53,129	.....	47,600	38,839
300	62,749	.....	.....	62,370	.....	.....	61,511	.....	58,537	.....	53,548	45,944
325	67,738	.....	.....	67,379	.....	.....	66,601	.....	63,866	.....	59,336	52,570
350	72,748	.....	.....	72,409	.....	.....	71,690	.....	69,135	.....	64,984	58,877
375	77,737	.....	.....	77,418	.....	.....	76,760	.....	74,384	.....	70,532	64,944
400	82,727	.....	.....	82,448	.....	.....	81,629	.....	79,594	.....	76,001	70,852

Capacity, in Cubic Feet, of 8″ Pipe Line 2 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,123	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,963	3,467	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	5,732	5,293	4,005	2,831	.....	.....	.....	.....	.....	.....	.....	.....
40	7,247	6,935	6,001	5,350	4,472	.....	.....	.....	.....	.....	.....	.....
50	8,747	8,493	7,756	7,247	6,638	4,897	.....	.....	.....	.....	.....	.....
60	10,234	10,007	9,384	.....	8,493	7,219	5,293	.....	.....	.....	.....	.....
70	11,692	.....	10,970	.....	10,205	9,172	7,742	.....	.....	.....	.....	.....
80	13,135	.....	12,498	.....	11,847	10,970	9,795	.....	.....	.....	.....	.....
90	14,593	.....	14,013	.....	13,433	12,654	11,677	7,643	.....	.....	.....	.....
100	16,037	.....	15,499	.....	14,933	14,155	13,433	10,134	.....	.....	.....	.....
125	19,618	.....	.....	18,996	.....	18,217	17,552	15,174	11,295	.....	.....	.....
150	23,185	.....	.....	22,662	.....	22,025	21,473	19,576	16,745	15,145	.....	.....
175	26,738	.....	.....	26,285	.....	.....	25,266	23,681	21,374	18,175	13,334	.....
200	30,305	.....	.....	29,909	.....	.....	29,003	27,644	25,719	23,100	19,519	.....
225	33,844	.....	.....	33,405	.....	.....	32,698	.....	29,725	27,588	24,629	15,004
250	37,397	.....	.....	37,086	.....	.....	36,364	.....	33,802	31,848	29,357	21,926
275	40,950	.....	.....	40,653	.....	.....	40,002	.....	37,680	.....	33,759	27,545
300	44,503	.....	.....	44,234	.....	.....	43,625	.....	41,516	.....	37,977	32,584
325	48,042	.....	.....	47,787	.....	.....	47,235	.....	45,296	.....	42,082	37,284
350	51,594	.....	.....	51,354	.....	.....	50,844	.....	49,032	.....	46,088	41,757
375	55,133	.....	.....	54,907	.....	.....	54,440	.....	52,755	.....	50,023	46,060
400	58,672	.....	.....	58,474	.....	.....	57,893	.....	56,450	.....	53,902	50,250

Capacity, in Cubic Feet, of 8″ Pipe Line 3 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,730	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,230	2,826	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,672	4,314	3,265	2,307	.....	.....	.....	.....	.....	.....	.....	.....
40	5,907	5,653	4,891	4,361	3,645	.....	.....	.....	.....	.....	.....	.....
50	7,130	6,922	6,322	5,907	5,411	3,991	.....	.....	.....	.....	.....	.....
60	8,341	8,156	7,649	.....	6,922	5,884	4,314	.....	.....	.....	.....	.....
70	9,529	.....	8,941	.....	8,318	7,476	6,310	.....	.....	.....	.....	.....
80	10,706	.....	10,187	.....	9,656	8,941	7,983	.....	.....	.....	.....	.....
90	11,895	.....	11,422	.....	10,948	10,314	9,518	6,230	.....	.....	.....	.....
100	13,071	.....	12,633	.....	12,171	11,537	10,948	8,260	.....	.....	.....	.....
125	15,990	.....	.....	15,483	.....	14,848	14,306	.....	9,206	.....	.....	.....
150	18,898	.....	.....	18,471	.....	17,952	17,502	15,956	13,648	12,345	.....	.....
175	21,794	.....	.....	21,424	.....	.....	20,594	19,302	17,421	14,814	10,868	.....
200	24,701	.....	.....	24,378	.....	.....	23,640	22,532	20,963	18,829	15,910	.....
225	27,585	.....	.....	27,228	.....	.....	26,651	.....	24,228	22,486	20,075	12,229
250	30,481	.....	.....	30,227	.....	.....	29,639	.....	27,551	25,959	23,928	17,871
275	33,377	.....	.....	33,135	.....	.....	32,604	.....	30,712	.....	27,516	22,451
300	36,273	.....	.....	36,054	.....	.....	35,558	.....	33,839	.....	30,954	26,559
325	39,157	.....	.....	38,950	.....	.....	38,500	.....	36,919	.....	34,300	30,389
350	42,053	.....	.....	41,857	.....	.....	41,442	.....	39,965	.....	37,565	34,035
375	44,938	.....	.....	44,753	.....	.....	44,372	.....	42,999	.....	40,773	37,542
400	47,822	.....	.....	47,660	.....	.....	47,187	.....	46,001	.....	43,934	40,957

Capacity, in Cubic Feet, of 8″ Pipe Line 4 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,496	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,794	2,444	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,041	3,732	2,824	1,995	.....	.....	.....	.....	.....	.....	.....	.....
40	5,109	4,889	4,231	3,772	3,153	.....	.....	.....	.....	.....	.....	.....
50	6,167	5,987	5,468	5,109	4,680	3,452	.....	.....	.....	.....	.....	.....
60	7,214	7,055	6,616	.....	5,987	5,089	3,732	.....	.....	.....	.....	.....
70	8,242	.....	7,733	.....	7,195	6,466	5,458	.....	.....	.....	.....	.....
80	9,260	.....	8,811	.....	8,352	7,733	6,905	.....	.....	.....	.....	.....
90	10,288	.....	9,879	.....	9,470	8,921	8,232	5,388	.....	.....	.....	.....
100	11,306	.....	10,927	.....	10,528	9,979	9,470	7,145	.....	.....	.....	.....
125	13,831	.....	.....	13,392	.....	12,843	12,374	10,697	7,963	.....	.....	.....
150	16,345	.....	.....	15,976	.....	15,527	15,138	13,801	11,805	10,677	.....	.....
175	18,850	.....	.....	18,531	.....	.....	17,812	16,695	15,068	12,813	9,400	.....
200	21,365	.....	.....	21,086	.....	.....	20,447	19,489	18,132	16,286	13,761	.....
225	23,860	.....	.....	23,550	.....	.....	23,051	.....	20,956	19,449	17,363	10,577
250	26,365	.....	.....	26,145	.....	.....	25,636	.....	23,830	22,453	20,696	15,457
275	28,869	.....	.....	28,660	.....	.....	28,201	.....	26,564	.....	23,800	19,419
300	31,374	.....	.....	31,185	.....	.....	30,755	.....	29,268	.....	26,774	22,972
325	33,869	.....	.....	33,689	.....	.....	33,300	.....	31,933	.....	29,668	26,275
350	36,374	.....	.....	36,204	.....	.....	35,845	.....	34,567	.....	32,492	29,438
375	38,868	.....	.....	38,709	.....	.....	38,380	.....	37,192	.....	35,266	32,472
400	41,363	.....	.....	41,224	.....	.....	40,814	.....	39,797	.....	38,000	35,426

Capacity, in Cubic Feet, of 8″ Pipe Line 5 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,336	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,494	2,182	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	3,608	3,332	2,521	1,782	.....	.....	.....	.....	.....	.....	.....	.....
40	4,561	4,365	3,777	3,367	2,815	.....	.....	.....	.....	.....	.....	.....
50	5,506	5,346	4,882	4,561	4,178	3,082	.....	.....	.....	.....	.....	.....
60	6,441	6,299	5,907	5,648	5,346	4,544	3,332	.....	.....	.....	.....	.....
70	7,359	.....	6,905	.....	6,424	5,773	4,873	.....	.....	.....	.....	.....
80	8,268	.....	7,867	.....	7,457	6,905	6,165	.....	.....	.....	.....	.....
90	9,186	.....	8,820	.....	8,455	7,965	7,350	4,811	.....	.....	.....	.....
100	10,095	.....	9,756	.....	9,400	8,910	8,455	6,379	.....	.....	.....	.....
125	12,349	.....	.....	11,957	.....	11,467	11,048	9,551	7,110	.....	.....	.....
150	14,594	.....	.....	14,264	.....	13,863	13,516	12,322	10,540	9,533	.....	.....
175	16,830	.....	.....	16,545	.....	.....	15,904	14,906	13,454	11,440	8,393	.....
200	19,076	.....	.....	18,826	.....	.....	18,256	17,401	16,189	14,541	12,286	.....
225	21,303	.....	.....	21,027	.....	.....	20,582	.....	18,711	17,365	15,503	9,444
250	23,540	.....	.....	23,344	.....	.....	22,889	.....	21,277	20,047	18,479	13,801
275	25,776	.....	.....	25,589	.....	.....	25,179	.....	23,718	.....	21,250	17,338
300	28,013	.....	.....	27,843	.....	.....	27,460	.....	26,133	.....	23,905	20,510
325	30,240	.....	.....	30,080	.....	.....	29,732	.....	28,512	.....	26,489	23,468
350	32,476	.....	.....	32,325	.....	.....	32,004	.....	30,864	.....	29,010	26,284
375	34,704	.....	.....	34,561	.....	.....	34,267	.....	33,207	.....	31,487	28,993
400	36,931	.....	.....	36,807	.....	.....	36,441	.....	35,533	.....	33,929	31,630

Capacity, in Cubic Feet, of 8″ Pipe Line 7 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,129	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,108	1,845	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	3,050	2,816	2,131	1,506	.....	.....	.....	.....	.....	.....	.....	.....
40	3,856	3,690	3,193	2,847	2,380	.....	.....	.....	.....	.....	.....	.....
50	4,654	4,519	4,127	3,856	3,532	2,606	.....	.....	.....	.....	.....	.....
60	5,445	5,325	4,993	.....	4,519	3,841	2,816	.....	.....	.....	.....	.....
70	6,221	.....	5,837	.....	5,430	4,880	4,119	.....	.....	.....	.....	.....
80	6,989	.....	6,650	.....	6,304	5,837	5,212	.....	.....	.....	.....	.....
90	7,765	.....	7,456	.....	7,147	6,733	6,213	4,067	.....	.....	.....	.....
100	8,533	.....	8,247	.....	7,946	7,531	7,147	5,392	.....	.....	.....	.....
125	10,439	.....	.....	10,107	.....	9,693	9,339	8,074	6,010	.....	.....	.....
150	12,337	.....	.....	12,058	.....	11,719	11,425	10,416	8,910	8,059	.....	.....
175	14,227	.....	.....	13,986	.....	.....	13,444	12,600	11,373	9,670	7,095	.....
200	16,125	.....	.....	15,914	.....	.....	15,432	14,709	13,685	12,292	10,386	.....
225	18,008	.....	.....	17,775	.....	.....	17,398	.....	15,816	14,679	13,105	7,983
250	19,899	.....	.....	19,733	.....	.....	19,349	.....	17,986	16,946	15,621	11,666
275	21,789	.....	.....	21,631	.....	.....	21,285	.....	20,049	.....	17,963	14,657
300	23,680	.....	.....	23,537	.....	.....	23,213	.....	22,091	.....	20,208	17,338
325	25,563	.....	.....	25,426	.....	.....	25,133	.....	24,102	.....	22,392	19,839
350	27,453	.....	.....	27,325	.....	.....	27,054	.....	26,090	.....	24,523	22,219
375	29,336	.....	.....	29,216	.....	.....	28,967	.....	28,071	.....	26,617	24,508
400	31,219	.....	.....	31,114	.....	.....	30,805	.....	30,037	.....	28,681	27,738

Capacity, in Cubic Feet, of 8″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	947	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,768	1,547	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,558	2,362	1,787	1,263	.....	.....	.....	.....	.....	.....	.....	.....
40	3,233	3,094	2,678	2,387	1,995	.....	.....	.....	.....	.....	.....	.....
50	3,903	3,789	3,461	3,233	2,962	2,185	.....	.....	.....	.....	.....	.....
60	4,566	4,465	4,187	.....	3,789	3,221	2,362	.....	.....	.....	.....	.....
70	5,217	.....	4,895	.....	4,553	4,092	3,454	.....	.....	.....	.....	.....
80	5,861	.....	5,577	.....	5,286	4,895	4,370	.....	.....	.....	.....	.....
90	6,512	.....	6,253	.....	5,994	5,646	5,210	3,410	.....	.....	.....	.....
100	7,156	.....	6,916	.....	6,663	6,316	5,994	4,522	.....	.....	.....	.....
125	8,754	.....	.....	8,476	.....	8,128	7,832	6,770	5,040	.....	.....	.....
150	10,345	.....	.....	10,112	.....	9,828	9,581	8,735	7,472	6,758	.....	.....
175	11,931	.....	.....	11,729	.....	.....	11,274	10,567	9,537	8,110	5,949	.....
200	13,522	.....	.....	13,346	.....	.....	12,941	12,335	11,476	10,308	8,710	.....
225	15,102	.....	.....	14,906	.....	.....	14,590	.....	13,264	12,310	10,990	6,695
250	16,687	.....	.....	16,548	.....	.....	16,226	.....	15,083	14,211	13,099	9,783
275	18,272	.....	.....	18,140	.....	.....	17,849	.....	16,813	.....	15,064	12,291
300	19,858	.....	.....	19,738	.....	.....	19,466	.....	18,525	.....	16,946	14,539
325	21,437	.....	.....	21,322	.....	.....	21,077	.....	20,211	.....	18,778	16,636
350	23,022	.....	.....	22,915	.....	.....	22,687	.....	21,879	.....	20,565	18,632
375	24,601	.....	.....	24,500	.....	.....	24,292	.....	23,540	.....	22,321	20,552
400	26,180	.....	.....	26,092	.....	.....	25,833	.....	25,189	.....	24,052	22,422

Capacity, in Cubic Feet, of 8″ Pipe Line 15 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	773	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,444	1,263	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,088	1,929	1,459	1,031	.....	.....	.....	.....	.....	.....	.....	.....
40	2,640	2,527	2,186	1,949	1,629	.....	.....	.....	.....	.....	.....	.....
50	3,187	3,094	2,826	2,640	2,419	1,784	.....	.....	.....	.....	.....	.....
60	3,729	3,646	3,419	.....	3,094	2,630	1,929	.....	.....	.....	.....	.....
70	4,260	.....	3,997	.....	3,718	3,342	2,821	.....	.....	.....	.....	.....
80	4,786	.....	4,554	.....	4,317	3,997	3,569	.....	.....	.....	.....	.....
90	5,317	.....	5,106	.....	4,894	4,611	4,255	2,785	.....	.....	.....	.....
100	5,843	.....	5,647	.....	5,441	5,157	4,894	3,693	.....	.....	.....	.....
125	7,148	.....	.....	6,921	.....	6,638	6,395	5,529	4,116	.....	.....	.....
150	8,448	.....	.....	8,257	.....	8,025	7,824	7,133	6,101	5,518	.....	.....
175	9,743	.....	.....	9,578	.....	.....	9,206	8,629	7,788	6,622	4,858	.....
200	11,043	.....	.....	10,898	.....	.....	10,568	10,073	9,371	8,417	7,112	.....
225	12,332	.....	.....	12,172	.....	.....	11,914	.....	10,831	10,052	8,974	5,467
250	13,627	.....	.....	13,513	.....	.....	13,250	.....	12,317	11,605	10,697	7,989
275	14,921	.....	.....	14,813	.....	.....	14,576	.....	13,730	.....	12,301	10,037
300	16,216	.....	.....	16,118	.....	.....	15,896	.....	15,128	.....	13,838	11,873
325	17,505	.....	.....	17,413	.....	.....	17,211	.....	16,505	.....	15,334	13,585
350	18,800	.....	.....	18,712	.....	.....	18,527	.....	17,866	.....	16,794	15,215
375	20,090	.....	.....	20,007	.....	.....	19,837	.....	19,223	.....	18,228	16,783
400	21,379	.....	.....	21,307	.....	.....	21,095	.....	20,569	.....	19,641	18,310

Capacity, in Cubic Feet, of 8″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	669	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,250	1,093	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,808	1,669	1,263	892	.....	.....	.....	.....	.....	.....	.....	.....
40	2,286	2,187	1,893	1,687	1,410	.....	.....	.....	.....	.....	.....	.....
50	2,759	2,678	2,446	2,286	2,094	1,544	.....	.....	.....	.....	.....	.....
60	3,228	3,156	2,960	.....	2,678	2,277	1,669	.....	.....	.....	.....	.....
70	3,688	.....	3,460	.....	3,219	2,893	2,442	.....	.....	.....	.....	.....
80	4,143	.....	3,942	.....	3,737	3,460	3,089	.....	.....	.....	.....	.....
90	4,603	.....	4,420	.....	4,237	3,991	3,683	2,411	.....	.....	.....	.....
100	5,058	.....	4,889	.....	4,710	4,464	4,237	3,196	.....	.....	.....	.....
125	6,188	.....	.....	5,991	.....	5,746	5,536	4,786	3,562	.....	.....	.....
150	7,313	.....	.....	7,148	.....	6,947	6,773	6,174	5,281	4,777	.....	.....
175	8,434	.....	.....	8,291	.....	.....	7,969	7,469	6,741	5,732	4,205	.....
200	9,559	.....	.....	9,434	.....	.....	9,148	8,719	8,112	7,286	6,157	.....
225	10,675	.....	.....	10,537	.....	.....	10,313	.....	9,376	8,702	7,768	4,732
250	11,796	.....	.....	11,698	.....	.....	11,470	.....	10,662	10,046	9,260	6,916
275	12,916	.....	.....	12,823	.....	.....	12,617	.....	11,885	.....	10,648	8,688
300	14,037	.....	.....	13,952	.....	.....	13,760	.....	13,095	.....	11,979	10,278
325	15,153	.....	.....	15,073	.....	.....	14,899	.....	14,287	.....	13,274	11,760
350	16,274	.....	.....	16,198	.....	.....	16,037	.....	15,466	.....	14,537	13,171
375	17,390	.....	.....	17,319	.....	.....	17,172	.....	16,640	.....	15,778	14,528
400	18,507	.....	.....	18,444	.....	.....	18,261	.....	17,806	.....	17,002	15,850

Capacity, in Cubic Feet, of 8″ Pipe Line 30 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	546	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,019	892	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,474	1,366	1,030	728	.....	.....	.....	.....	.....	.....	.....	.....
40	1,864	1,784	1,543	1,376	1,150	.....	.....	.....	.....	.....	.....	.....
50	2,250	2,184	1,995	1,864	1,707	1,259	.....	.....	.....	.....	.....	.....
60	2,632	2,574	2,414	.....	2,184	1,857	1,361	.....	.....	.....	.....	.....
70	3,007	.....	2,821	.....	2,625	2,359	1,991	.....	.....	.....	.....	.....
80	3,379	.....	3,215	.....	3,047	2,821	2,519	.....	.....	.....	.....	.....
90	3,754	.....	3,604	.....	3,455	3,255	3,003	1,966	.....	.....	.....	.....
100	4,125	.....	3,987	.....	3,841	3,641	3,455	2,607	.....	.....	.....	.....
125	5,046	.....	.....	4,886	.....	4,686	4,515	3,903	2,905	.....	.....	.....
150	5,964	.....	.....	5,829	.....	5,665	5,523	5,035	4,307	3,896	.....	.....
175	6,878	.....	.....	6,761	.....	.....	6,499	6,091	5,498	4,675	3,430	.....
200	7,795	.....	.....	7,693	.....	.....	7,460	7,111	6,616	5,942	5,021	.....
225	8,701	.....	.....	8,593	.....	.....	8,411	.....	7,646	7,096	6,335	3,859
250	9,620	.....	.....	9,539	.....	.....	9,354	.....	8,695	8,192	7,551	5,640
275	10,533	.....	.....	10,457	.....	.....	10,290	.....	9,692	.....	8,684	7,085
300	11,447	.....	.....	11,378	.....	.....	11,222	.....	10,679	.....	9,769	8,382
325	12,358	.....	.....	12,292	.....	.....	12,150	.....	11,651	.....	10,825	9,590
350	13,272	.....	.....	13,210	.....	.....	13,079	.....	12,613	.....	11,855	10,741
375	14,182	.....	.....	14,124	.....	.....	14,004	.....	13,570	.....	12,868	11,848
400	15,092	.....	.....	15,041	.....	.....	14,892	.....	14,521	.....	13,865	12,926

Capacity, in Cubic Feet, of 8″ Pipe Line 40 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	473	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	884	773	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,279	1,181	893	631	.....	.....	.....	.....	.....	.....	.....	.....
40	1,616	1,547	1,339	1,193	997	.....	.....	.....	.....	.....	.....	.....
50	1,951	1,894	1,730	1,616	1,481	1,092	.....	.....	.....	.....	.....	.....
60	2,283	2,232	2,093	.....	1,894	1,610	1,181	.....	.....	.....	.....	.....
70	2,608	.....	2,447	.....	2,276	2,046	1,727	.....	.....	.....	.....	.....
80	2,930	.....	2,788	.....	2,643	2,447	2,185	.....	.....	.....	.....	.....
90	3,256	.....	3,126	.....	2,997	2,823	2,605	1,705	.....	.....	.....	.....
100	3,578	.....	3,458	.....	3,331	3,158	2,997	2,261	.....	.....	.....	.....
125	4,377	.....	.....	4,238	.....	4,064	3,916	3,385	2,520	.....	.....	.....
150	5,172	.....	.....	5,056	.....	4,914	4,790	4,367	3,736	3,379	.....	.....
175	5,965	.....	.....	5,864	.....	.....	5,637	5,283	4,768	4,055	2,974	.....
200	6,761	.....	.....	6,673	.....	.....	6,470	6,167	5,738	5,154	4,355	.....
225	7,551	.....	.....	7,453	.....	.....	7,295	.....	6,632	6,155	5,495	3,347
250	8,343	.....	.....	8,274	.....	.....	8,113	.....	7,541	7,105	6,549	4,891
275	9,136	.....	.....	9,070	.....	.....	8,924	.....	8,406	.....	7,532	6,145
300	9,929	.....	.....	9,869	.....	.....	9,733	.....	9,262	.....	8,473	7,269
325	10,718	.....	.....	10,661	.....	.....	10,538	.....	10,105	.....	9,389	8,318
350	11,511	.....	.....	11,457	.....	.....	11,343	.....	10,939	.....	10,282	9,316
375	12,300	.....	.....	12,250	.....	.....	12,146	.....	11,770	.....	11,160	10 276
400	13,090	.....	.....	13,046	.....	.....	12,916	.....	12,594	.....	12,026	11,211

292 Capacity, in Cubic Feet, of 8″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	423	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	790	691	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,143	1,055	799	564	.....	.....	.....	.....	.....	.....	.....	.....
40	1,445	1,383	1,197	1,067	892	.....	.....	.....	.....	.....	.....	.....
50	1,744	1,694	1,547	1,445	1,324	976	.....	.....	.....	.....	.....	.....
60	2,041	1,996	1,871	.....	1,694	1,439	1,055	.....	.....	.....	.....	.....
70	2,332	.....	2,188	.....	2,035	1,829	1,544	.....	.....	.....	.....	.....
80	2,620	.....	2,493	.....	2,363	2,188	1,953	.....	.....	.....	.....	.....
90	2,910	.....	2,795	.....	2,679	2,524	2,329	1,524	.....	.....	.....	.....
100	3,198	.....	3,091	.....	2,978	2,823	2,679	2,021	.....	.....	.....	.....
125	3,913	.....	.....	3,789	.....	3,633	3,501	3,026	2,253	.....	.....	.....
150	4,624	.....	.....	4,520	.....	4,393	4,283	3,904	3,340	3,021	.....	.....
175	5,333	.....	.....	5,243	.....	.....	5,039	4,723	4,263	3,625	2,659	.....
200	6,044	.....	.....	5,965	.....	.....	5,785	5,514	5,130	4,607	3,893	.....
225	6,750	.....	.....	6,663	.....	.....	6,522	.....	5,929	5,502	4,912	2,992
250	7,459	.....	.....	7,397	.....	.....	7,253	.....	6,742	6,352	5,855	4,373
275	8,168	.....	.....	8,108	.....	.....	7,978	.....	7,515	.....	6,733	5,494
300	8,876	.....	.....	8,823	.....	.....	8,701	.....	8,281	.....	7,575	6,499
325	9,582	.....	.....	9,531	.....	.....	9,421	.....	9,034	.....	8,393	7,436
350	10,291	.....	.....	10,243	.....	.....	10,141	.....	9,780	.....	9,192	8,329
375	10,997	.....	.....	10,951	.....	.....	10,858	.....	10,522	.....	9,977	9,187
400	11,702	.....	.....	11,663	.....	.....	11,547	.....	11,259	.....	10,751	10,023

Capacity, in Cubic Feet, of 8″ Pipe Line 70 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	357	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	667	584	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	965	891	674	476	.....	.....	.....	.....	.....	.....	.....	.....
40	1,220	1,168	1,010	901	753	.....	.....	.....	.....	.....	.....	.....
50	1,473	1,430	1,306	1,220	1,118	824	.....	.....	.....	.....	.....	.....
60	1,723	1,685	1,580	.....	1,430	1,215	891	.....	.....	.....	.....	.....
70	1,969	.....	1,847	.....	1,718	1,544	1,303	.....	.....	.....	.....	.....
80	2,212	.....	2,104	.....	1,995	1,847	1,649	.....	.....	.....	.....	.....
90	2,457	.....	2,360	.....	2,262	2,131	1,966	1,287	.....	.....	.....	.....
100	2,700	.....	2,610	.....	2,515	2,383	2,262	1,706	.....	.....	.....	.....
125	3,304	.....	.....	3,199	.....	3,068	2,956	2,555	1,902	.....	.....	.....
150	3,904	.....	.....	3,816	.....	3,709	3,616	3,296	2,820	2,550	.....	.....
175	4,503	.....	.....	4,426	.....	.....	4,255	3,988	3,599	3,060	2,245	.....
200	5,103	.....	.....	5,007	.....	.....	4,884	4,655	4,331	3,890	3,287	.....
225	5,699	.....	.....	5,626	.....	.....	5,506	.....	5,006	4,646	4,147	2,526
250	6,298	.....	.....	6,245	.....	.....	6,124	.....	5,692	5,363	4,944	3,692
275	6,896	.....	.....	6,846	.....	.....	6,736	.....	6,345	.....	5,685	4,639
300	7,494	.....	.....	7,449	.....	.....	7,347	.....	6,991	.....	6,396	5,487
325	8,090	.....	.....	8,048	.....	.....	7,955	.....	7,628	.....	7,087	6,279
350	8,689	.....	.....	8,648	.....	.....	8,562	.....	8,257	.....	7,761	7,032
375	9,285	.....	.....	9,247	.....	.....	9,168	.....	8,884	.....	8,424	7,757
400	9,881	.....	.....	9,847	.....	.....	9,750	.....	9,506	.....	9,077	8,462

Capacity, in Cubic Feet, of 8″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	299	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	558	488	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	808	746	564	399	.....	.....	.....	.....	.....	.....	.....	.....
40	1,021	977	846	745	630	.....	.....	.....	.....	.....	.....	.....
50	1,233	1,197	1,093	1,021	936	690	.....	.....	.....	.....	.....	.....
60	1,442	1,411	1,323	.....	1,197	1,017	746	.....	.....	.....	.....	.....
70	1,648	.....	1,546	.....	1,438	1,293	1,091	.....	.....	.....	.....	.....
80	1,852	.....	1,762	.....	1,670	1,546	1,381	.....	.....	.....	.....	.....
90	2,057	.....	1,975	.....	1,894	1,784	1,646	1,077	.....	.....	.....	.....
100	2,261	.....	2,185	.....	2,105	1,995	1,894	1,428	.....	.....	.....	.....
125	2,766	.....	.....	2,678	.....	2,568	2,474	2,139	1,592	.....	.....	.....
150	3,269	.....	.....	3,195	.....	3,105	3,027	2,760	2,361	2,135	.....	.....
175	3,770	.....	.....	3,706	.....	.....	3,562	3,338	3,013	2,562	1,880	.....
200	4,273	.....	.....	4,217	.....	.....	4,089	3,807	3,626	3,257	2,752	.....
225	4,771	.....	.....	4,710	.....	.....	4,610	.....	4,191	3,889	3,472	2,115
250	5,272	.....	.....	5,228	.....	.....	5,127	.....	4,765	4,490	4,139	3,091
275	5,773	.....	.....	5,731	.....	.....	5,640	.....	5,312	.....	4,759	3,883
300	6,274	.....	.....	6,236	.....	.....	6,151	.....	5,853	.....	5,354	4,594
325	6,773	.....	.....	6,737	.....	.....	6,659	.....	6,386	.....	5,933	5,256
350	7,274	.....	.....	7,240	.....	.....	7,168	.....	6,913	.....	6,498	5,887
375	7,773	.....	.....	7,741	.....	.....	7,675	.....	7,438	.....	7,053	6,494
400	8,272	.....	.....	8,244	.....	.....	8,162	.....	7,959	.....	7,600	7,085

Capacity, in Cubic Feet, of 10″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,674	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,126	2,735	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,521	4,175	3,159	2,233	.....	.....	.....	.....	.....	.....	.....	.....
40	5,716	5,470	4,733	4,220	3,528	.....	.....	.....	.....	.....	.....	.....
50	6,899	6,699	6,118	5,716	5,236	3,863	.....	.....	.....	.....	.....	.....
60	8,072	7,893	7,402	.....	6,699	5,694	4,175	.....	.....	.....	.....	.....
70	9,222	.....	8,652	.....	8,049	7,234	6,107	.....	.....	.....	.....	.....
80	10,361	.....	9,858	.....	9,345	8,652	7,726	.....	.....	.....	.....	.....
90	11,511	.....	11,053	.....	10,595	9,981	9,211	6,029	.....	.....	.....	.....
100	12,649	.....	12,225	.....	11,779	11,165	10,595	7,994	.....	.....	.....	.....
125	15,474	.....	.....	14,983	.....	14,369	13,844	11,968	8,909	.....	.....	.....
150	18,288	.....	.....	17,875	.....	17,372	16,937	15,441	13,208	11,946	.....	.....
175	21,090	.....	.....	20,733	.....	.....	19,929	18,679	16,859	14,335	10,517	.....
200	23,904	.....	.....	23,591	.....	.....	22,877	21,805	20,286	18,221	15,396	.....
225	26,695	.....	.....	26,349	.....	.....	25,791	.....	23,446	21,760	19,427	11,834
250	29,497	.....	.....	29,252	.....	.....	28,682	.....	26,662	25,121	23,156	17,295
275	32,300	.....	.....	32,065	.....	.....	31,552	.....	29,721	.....	26,628	21,727
300	35,102	.....	.....	34,890	.....	.....	34,410	.....	32,746	.....	29,955	25,701
325	37,894	.....	.....	37,715	.....	.....	37,257	.....	35,728	.....	33,193	29,408
350	40,696	.....	.....	40,506	.....	.....	40,104	.....	38,675	.....	36,353	32,936
375	43,487	.....	.....	43,309	.....	.....	42,940	.....	41,611	.....	39,457	36,330
400	46,278	.....	.....	46,122	.....	.....	45,664	.....	44,526	.....	42,516	39,635

Capacity, in Cubic Feet, of 10″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,183	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,209	1,933	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	3,196	2,951	2,233	1,578	.....	.....	.....	.....	.....	.....	.....	.....
40	4,040	3,867	3,346	2,983	2,494	.....	.....	.....	.....	.....	.....	.....
50	4,877	4,735	4,325	4,040	3,701	2,730	.....	.....	.....	.....	.....	.....
60	5,706	5,579	5,232	.....	4,735	4,025	2,951	.....	.....	.....	.....	.....
70	6,519	.....	6,116	.....	5,690	5,114	4,317	.....	.....	.....	.....	.....
80	7,324	.....	6,969	.....	6,606	6,116	5,461	.....	.....	.....	.....	.....
90	8,137	.....	7,813	.....	7,489	7,055	6,511	4,261	.....	.....	.....	.....
100	8,942	.....	8,642	.....	8,326	7,892	7,489	5,651	.....	.....	.....	.....
125	10,939	.....	.....	10,591	.....	10,157	9,786	8,460	6,298	.....	.....	.....
150	12,927	.....	.....	12,635	.....	12,280	11,972	10,915	9,336	8,444	.....	.....
175	14,908	.....	.....	14,656	.....	.....	14,088	13,204	11,917	10,133	7,434	.....
200	16,897	.....	.....	16,676	.....	.....	16,171	15,414	14,340	12,880	10,883	.....
225	18,870	.....	.....	18,626	.....	.....	18,231	.....	16,573	15,382	13,732	8,366
250	20,852	.....	.....	20,678	.....	.....	20,275	.....	18,847	17,758	16,369	12,225
275	22,833	.....	.....	22,667	.....	.....	22,304	.....	21,009	.....	18,823	15,358
300	24,814	.....	.....	24,664	.....	.....	24,324	.....	23,148	.....	21,175	18,168
325	26,787	.....	.....	26,660	.....	.....	26,337	.....	25,256	.....	23,464	20,788
350	28,768	.....	.....	28,633	.....	.....	28,349	.....	27,339	.....	25,697	23,282
375	30,741	.....	.....	30,615	.....	.....	30,354	.....	29,415	.....	27,892	25,682
400	32,714	.....	.....	32,603	.....	.....	32,280	.....	31,475	.....	30,054	28,018

Capacity, in Cubic Feet, of 10″ Pipe Line 30 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	965	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,802	1,576	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,606	2,407	1,821	1,287	.....	.....	.....	.....	.....	.....	.....	.....
40	3,295	3,153	2,729	2,432	2,033	.....	.....	.....	.....	.....	.....	.....
50	3,977	3,861	3,527	3,295	3,018	2,227	.....	.....	.....	.....	.....	.....
60	4,653	4,550	4,267	.....	3,861	3,282	2,407	.....	.....	.....	.....	.....
70	5,316	.....	4,988	.....	4,640	4,170	3,520	.....	.....	.....	.....	.....
80	5,973	.....	5,683	.....	5,387	4,988	4,454	.....	.....	.....	.....	.....
90	6,636	.....	6,372	.....	6,108	5,754	5,310	3,475	.....	.....	.....	.....
100	7,292	.....	7,047	.....	6,790	6,436	6,108	4,608	.....	.....	.....	.....
125	8,920	.....	.....	8,637	.....	8,283	7,981	6,899	5,136	.....	.....	.....
150	10,542	.....	.....	10,304	.....	10,015	9,764	8,901	7,614	6,887	.....	.....
175	12,158	.....	.....	11,952	.....	.....	11,489	10,768	9,719	8,264	6,063	.....
200	13,780	.....	.....	13,600	.....	.....	13,188	12,570	11,695	10,504	8,875	.....
225	15,389	.....	.....	15,190	.....	.....	14,868	.....	13,516	12,544	11,199	6,822
250	17,005	.....	.....	16,863	.....	.....	16,535	.....	15,370	14,482	13,349	9,970
275	18,620	.....	.....	18,485	.....	.....	18,189	.....	17,133	.....	15,351	12,525
300	20,236	.....	.....	20,114	.....	.....	19,837	.....	18,878	.....	17,269	14,816
325	21,845	.....	.....	21,726	.....	.....	21,478	.....	20,596	.....	19,135	16,953
350	23,461	.....	.....	23,351	.....	.....	23,119	.....	22,296	.....	20,957	18,987
375	25,070	.....	.....	24,967	.....	.....	24,754	.....	23,988	.....	22,746	20,944
400	26,679	.....	.....	26,589	.....	.....	26,325	.....	25,668	.....	24,510	22,849

Capacity, in Cubic Feet, of 10″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	748	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,397	1,222	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,021	1,866	1,412	998	.....	.....	.....	.....	.....	.....	.....	.....
40	2,555	2,445	2,116	1,886	1,577	.....	.....	.....	.....	.....	.....	.....
50	3,084	2,994	2,735	2,555	2,340	1,726	.....	.....	.....	.....	.....	.....
60	3,608	3,528	3,309	.....	2,994	2,545	1,866	.....	.....	.....	.....	.....
70	4,122	.....	3,868	.....	3,598	3,234	2,730	.....	.....	.....	.....	.....
80	4,631	.....	4,407	.....	4,177	3,868	3,453	.....	.....	.....	.....	.....
90	5,145	.....	4,941	.....	4,736	4,461	4,117	2,695	.....	.....	.....	.....
100	5,564	.....	5,465	.....	5,265	4,991	4,736	3,573	.....	.....	.....	.....
125	6,917	.....	.....	6,697	.....	6,423	6,188	5,350	3,982	.....	.....	.....
150	8,175	.....	.....	7,990	.....	7,765	7,571	6,902	5,904	5,340	.....	.....
175	9,427	.....	.....	9,268	.....	.....	8,908	8,349	7,536	6,408	4,701	.....
200	10,685	.....	.....	10,545	.....	.....	10,226	9,747	9,068	8,145	6,882	.....
225	11,993	.....	.....	11,778	.....	.....	11,529	.....	10,481	9,727	8,684	5,290
250	13,186	.....	.....	13,076	.....	.....	12,821	.....	11,918	11,229	10,351	7,731
275	14,438	.....	.....	14,334	.....	.....	14,104	.....	13,286	.....	11,903	9,712
300	15,691	.....	.....	15,596	.....	.....	15,382	.....	14,638	.....	13,390	11,489
325	16,939	.....	.....	16,849	.....	.....	16,654	.....	15,971	.....	14,838	13,146
350	18,192	.....	.....	18,107	.....	.....	17,927	.....	17,288	.....	16,250	14,723
375	19,439	.....	.....	19,360	.....	.....	19,195	.....	18,601	.....	17,638	16,240
400	20,687	.....	.....	20,617	.....	.....	20,413	.....	19,904	.....	19,005	17,718

Capacity, in Cubic Feet, of 10″ Pipe Line 100 Miles Long. for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	529	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	987	865	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,428	1,319	998	705	.....	.....	.....	.....	.....	.....	.....	.....
40	1,806	1,728	1,495	1,333	1,114	.....	.....	.....	.....	.....	.....	.....
50	2,180	2,116	1,933	1,806	1,654	1,220	.....	.....	.....	.....	.....	.....
60	2,550	2,494	2,339	.....	2,116	1,799	1,319	.....	.....	.....	.....	.....
70	2,914	.....	2,734	.....	2,543	2,286	1,929	.....	.....	.....	.....	.....
80	3,273	.....	3,115	.....	2,952	2,734	2,441	.....	.....	.....	.....	.....
90	3,637	.....	3,492	.....	3,348	3,154	2,910	1,905	.....	.....	.....	.....
100	3,997	.....	3,863	.....	3,722	3,528	3,348	2,526	.....	.....	.....	.....
125	4,889	.....	.....	4,734	.....	4,540	4,374	3,782	2,815	.....	.....	.....
150	5,778	.....	.....	5,648	.....	5,489	5,351	4,879	4,173	3,774	.....	.....
175	6,664	.....	.....	6,551	.....	.....	6,297	5,902	5,327	4,529	3,323	.....
200	7,553	.....	.....	7,454	.....	.....	7,228	6,890	6,410	5,757	4,865	.....
225	8,435	.....	.....	8,326	.....	.....	8,149	.....	7,408	6,876	6,138	3,739
250	9,320	.....	.....	9,243	.....	.....	9,063	.....	8,424	7,938	7,317	5,464
275	10,206	.....	.....	10,132	.....	.....	9,970	.....	9,391	.....	8,414	6,865
300	11,092	.....	.....	11,025	.....	.....	10,873	.....	10,347	.....	9,465	8,121
325	11,974	.....	.....	11,910	.....	.....	11,772	.....	11,289	.....	10,488	9,292
350	12,859	.....	.....	12,799	.....	.....	12,672	.....	12,220	.....	11,487	10,407
375	13,741	.....	.....	13,685	.....	.....	13,568	.....	13,148	.....	12,467	11,480
400	14,623	.....	.....	14,574	.....	.....	14,429	.....	14,069	.....	13,424	12,524

Capacity, in Cubic Feet, of 10″ Pipe Line 150 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	432											
20	806	705										
30	1,166	1,077	815	576								
40	1,474	1,411	1,221	1,088	910							
50	1,780	1,728	1,578	1,474	1,350	996						
60	2,082	2,036	1,909		1,728	1,469	1,077					
70	2,379		2,232		2,076	1,866	1,575					
80	2,673		2,543		2,410	2,232	1,993					
90	2,969		2,851		2,733	2,575	2,376	1,555				
100	3,263		3,154		3,038	2,880	2,733	2,062				
125	3,992			3,865		3,707	3,571	3,087	2,298			
150	4,718			4,611		4,482	4,369	3,983	3,407	3,082		
175	5,441			5,349			5,141	4,819	4,349	3,698	2,713	
200	6,167			6,086			5,902	5,625	5,233	4,700	3,972	
225	6,887			6,797			6,653		6,049	5,614	5,012	3,053
250	7,610			7,546			7,400		6,878	6,481	5,974	4,461
275	8,333			8,272			8,140		7,667		6,869	5,605
300	9,056			9,001			8,877		8,448		7,728	6,630
325	9,776			9,724			9,612		9,217		8,563	7,587
350	10,499			10,450			10,346		9,978		9,378	8,497
375	11,219			11,173			11,078		10,735		10,179	9,387
400	11,939			11,899			11,781		11,487		10,968	10,225

Capacity, in Cubic Feet, of 12″ Pipe Line 10 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,660											
20	4,966	4,345										
30	7,183	6,633	5,019	3,547								
40	9,081	8,690	7,520	6,704	5,604							
50	10,961	10,641	9,719	9,081	8,318	6,136						
60	12,823	12,539	11,759		10,641	9,045	6,633					
70	14,650		13,745		12,787	11,493	9,701					
80	16,459		15,661		14,845	13,745	12,273					
90	18,286		17,559		16,831	15,856	14,632	9,577				
100	20,095		19,421		18,711	17,736	16,831	12,699				
125	24,582			23,802		22,826	21,993	19,013	14,153			
150	29,052			28,395		27,597	26,906	24,529	20,982	18,977		
175	33,504			32,936			31,659	28,672	26,781	22,773	16,707	
200	37,973			37,477			36,341	34,639	32,227	28,945	24,458	
225	42,407			41,857			40,971		37,246	34,568	30,861	18,800
250	46,859			46,469			45,564		42,354	39,906	36,785	27,473
275	51,311			50,938			50,123		47,214		42,301	34,515
300	55,763			55,426			54,663		52,020		47,586	40,829
325	60,197			59,913			59,186		56,756		52,730	46,717
350	64,649			64,347			63,709		61,438		57,749	52,322
375	69,083			68,799			68,214		66,103		62,680	57,714
400	73,517			73,269			72,541		70,732		67,540	62,964

Capacity, in Cubic Feet, of 12″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,880	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,510	3.071	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	5,077	4,689	3,548	2,507	.....	.....	.....	.....	.....	.....	.....	.....
40	6,419	6,143	5,316	4,739	3,961	.....	.....	.....	.....	.....	.....	.....
50	7,748	7,522	6,870	6,419	5,880	4,338	.....	.....	.....	.....	.....	.....
60	9,064	8,864	8,312	.....	7,522	6,394	4,689	.....	.....	.....	.....	.....
70	10,356	.....	9,716	.....	9,039	8,124	6,858	.....	.....	.....	.....	.....
80	11,635	.....	11,070	.....	10,494	9,716	8,676	.....	.....	.....	.....	.....
90	12,926	.....	12,412	.....	11,898	11,208	10,343	6,770	.....	.....	.....	.....
100	14,205	.....	13,728	.....	13,227	12,537	11,898	8,977	.....	.....	.....	.....
125	17,377	.....	.....	16,825	.....	16,136	15,546	13,440	10,005	.....	.....	.....
150	20,536	.....	.....	20,073	.....	19,508	19,019	17,339	14,832	13,415	.....	.....
175	23,683	.....	.....	23,282	.....	.....	22,379	20,975	18,932	16,098	11,810	.....
200	26,843	.....	.....	26,492	.....	.....	25,689	24,486	22,781	20,461	17,289	.....
225	29,977	.....	.....	29,589	.....	.....	28,962	.....	26,329	24,436	21,815	13,290
250	33,124	.....	.....	32,849	.....	.....	32 209	.....	29,940	28,210	26,003	19,421
275	36,271	.....	.....	36,008	.....	.....	35,431	.....	33,375	.....	29,902	24,398
300	39,418	.....	.....	39,180	.....	.....	38,641	.....	36,773	.....	33,638	28,862
325	42,553	.....	.....	42,352	.....	.....	41,838	.....	40,120	.....	37,274	33,024
350	45,700	.....	.....	45,487	.....	.....	45,035	.....	43,430	.....	40,823	36,986
375	48,834	.....	.....	48,634	.....	.....	48,220	.....	46,728	.....	44,308	40,798
400	51,969	.....	.....	51,793	.....	.....	51,279	.....	50,000	.....	47,743	44,509

Capacity, in Cubic Feet, of 12″ Pipe Line 30 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,533	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,862	2,505	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,141	3,824	2,893	2,044	.....	.....	.....	.....	.....	.....	.....	.....
40	5,235	5,010	4,335	3,864	3,231	.....	.....	.....	.....	.....	.....	.....
50	6,318	6,134	5,603	5,235	4,795	3,537	.....	.....	.....	.....	.....	.....
60	7,392	7,228	6,779	.....	6,134	5,214	3,824	.....	.....	.....	.....	.....
70	8,445	.....	7,924	.....	7,372	6,625	5,592	.....	.....	.....	.....	.....
80	9,488	.....	9,028	.....	8,558	7,924	7,075	.....	.....	.....	.....	.....
90	10,541	.....	10,122	.....	9,703	9,140	8,435	5,521	.....	.....	.....	.....
100	11,584	.....	11,196	.....	10,787	10,224	9,703	7,320	.....	.....	.....	.....
125	14,171	.....	.....	13,721	.....	13,159	12,678	10,960	8,159	.....	.....	.....
150	16,748	.....	.....	16,369	.....	15,909	15,511	14,140	12,095	10,940	.....	.....
175	19,314	.....	.....	18,987	.....	.....	18,251	17,106	15,439	13,128	9,631	.....
200	21,891	.....	.....	21,605	.....	.....	20,950	19,969	18,578	16,686	14,099	.....
225	24,447	.....	.....	24,130	.....	.....	23,619	.....	21,472	19,928	17,791	10,838
250	27,013	.....	.....	26,788	.....	.....	26,267	.....	24,416	23,005	21,206	15,838
275	29,580	.....	.....	29,365	.....	.....	28,895	.....	27,218	.....	24,386	19,897
300	32,146	.....	.....	31,952	.....	.....	31,512	.....	29,989	.....	27,433	23,537
325	34,702	.....	.....	34,539	.....	.....	34,120	.....	32,719	.....	30,398	26,932
350	37,269	.....	.....	37,095	.....	.....	36,727	.....	35,418	.....	33,291	30,163
375	39,825	.....	.....	39,661	.....	.....	39,324	.....	38,107	.....	36,134	33,271
400	42,381	.....	.....	42,238	.....	.....	41,819	.....	40,776	.....	38,936	36,298

Capacity, in Cubic Feet, of 12″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,189	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,219	1,942	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	3,211	2,965	2,243	1,585	.....	.....	.....	.....	.....	.....	.....	.....
40	4,059	3,884	3,361	2,996	2,505	.....	.....	.....	.....	.....	.....	.....
50	4,899	4,757	4,344	4,059	3,718	2,743	.....	.....	.....	.....	.....	.....
60	5,732	5,605	5,256	.....	4,757	4,043	2,965	.....	.....	.....	.....	.....
70	6,548	.....	6,144	.....	5,716	5,137	4,336	.....	.....	.....	.....	.....
80	7,357	.....	7,000	.....	6,636	6,144	5,486	.....	.....	.....	.....	.....
90	8,174	.....	7,849	.....	7,524	7,088	6,531	4,281	.....	.....	.....	.....
100	8,982	.....	8,681	.....	8,364	7,928	7,524	5,676	.....	.....	.....	.....
125	10,988	.....	.....	10,640	.....	10,203	9,831	8,499	6,326	.....	.....	.....
150	12,986	.....	.....	12,693	.....	12,336	12,027	10,965	9,379	8,483	.....	.....
175	14,976	.....	.....	14,723	.....	.....	14,152	13,264	11,972	10,180	7,468	.....
200	16,974	.....	.....	16,752	.....	.....	16,245	15,484	14,406	12,939	10,933	.....
225	18,957	.....	.....	18,711	.....	.....	18,314	.....	16,649	15,452	13,795	8,404
250	20,947	.....	.....	20,772	.....	.....	20,368	.....	18,933	17,839	16,443	12,281
275	22,937	.....	.....	22,770	.....	.....	22,405	.....	21,105	.....	18,909	15,428
300	24,927	.....	.....	24,776	.....	.....	24,435	.....	23,254	.....	21,272	18,251
325	26,909	.....	.....	26,766	.....	.....	26,457	.....	25,371	.....	23,571	20,883
350	28,899	.....	.....	28,764	.....	.....	28,479	.....	27,464	.....	25,815	23,389
375	30,881	.....	.....	30,754	.....	.....	30,493	.....	29,549	.....	28,019	25,799
400	32,863	.....	.....	32,752	.....	.....	32,427	.....	31,618	.....	30,191	28,146

Capacity, in Cubic Feet, of 12″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	840	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,569	1,373	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,269	2,096	1,586	1,120	.....	.....	.....	.....	.....	.....	.....	.....
40	2,869	2,746	2,376	2,118	1,770	.....	.....	.....	.....	.....	.....	.....
50	3,463	3,362	3,071	2,869	2,628	1,939	.....	.....	.....	.....	.....	.....
60	4,051	3,962	3,715	.....	3,362	2,851	2,096	.....	.....	.....	.....	.....
70	4,629	.....	4,343	.....	4,040	3,631	3,065	.....	.....	.....	.....	.....
80	5,200	.....	4,948	.....	4,690	4,343	3,878	.....	.....	.....	.....	.....
90	5,778	.....	5,548	.....	5,318	5,010	4,623	3,026	.....	.....	.....	.....
100	6,349	.....	6,136	.....	5,912	5,604	5,318	4,012	.....	.....	.....	.....
125	7,767	.....	.....	7,521	.....	7,212	6,949	6,007	4,472	.....	.....	.....
150	9,180	.....	.....	8,972	.....	8,720	8,501	7,750	6,630	5,996	.....	.....
175	10,586	.....	.....	10,407	.....	.....	10,003	9,376	8,462	7,196	5,279	.....
200	11,999	.....	.....	11,842	.....	.....	11,483	10,945	10,183	9,146	7,728	.....
225	13,400	.....	.....	13,266	.....	.....	12,946	.....	11,769	10,922	9,751	5,940
250	14,806	.....	.....	14,683	.....	.....	14,397	.....	13,383	12,609	11,623	8,681
275	16,213	.....	.....	16,095	.....	.....	15,838	.....	14,918	.....	13,366	10,996
300	17,620	.....	.....	17,513	.....	.....	17,272	.....	16,437	.....	15,036	12,901
325	19,021	.....	.....	18,920	.....	.....	18,701	.....	17,934	.....	16,661	14,761
350	20,428	.....	.....	20,332	.....	.....	20,131	.....	19,413	.....	18,247	16,532
375	21,829	.....	.....	21,739	.....	.....	21,554	.....	20,887	.....	19,805	18,236
400	23,230	.....	.....	23,151	.....	.....	22,921	.....	22,350	.....	21,341	19,895

Capacity, in Cubic Feet, of 12″ Pipe Line 150 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	686	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	1,281	1,121	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	1,853	1,711	1,294	915	.....	.....	.....	.....	.....	.....	.....	.....
40	2,342	2,242	1,940	1,729	1,445	.....	.....	.....	.....	.....	.....	.....
50	2,827	2,745	2,507	2,342	2,146	1,583	.....	.....	.....	.....	.....	.....
60	3,308	3,235	3,033	.....	2,745	2,333	1,711	.....	.....	.....	.....	.....
70	3,779	.....	3,546	.....	3,299	2,965	2,502	.....	.....	.....	.....	.....
80	4,246	.....	4,040	.....	3,829	3,546	3,166	.....	.....	.....	.....	.....
90	4,717	.....	4,530	.....	4,342	4,090	3,775	2,470	.....	.....	.....	.....
100	5,184	.....	5,010	.....	4,827	4,575	4,342	3,276	.....	.....	.....	.....
125	6,342	.....	.....	6,140	.....	5,889	5,673	4,905	3,651	.....	.....	.....
150	7,495	.....	.....	7,325	.....	7,119	6,941	6,328	5,413	4,896	.....	.....
175	8,643	.....	.....	8,497	.....	.....	8,167	7,655	6,909	5,875	4,310	.....
200	9,796	.....	.....	9,668	.....	.....	9,375	8,936	8,314	7,467	6,310	.....
225	10,940	.....	.....	10,798	.....	.....	10,570	.....	9,609	8,918	7,961	4,850
250	12,089	.....	.....	11,988	.....	.....	11,755	.....	10,927	10,295	9,490	7,087
275	13,237	.....	.....	13,141	.....	.....	12,931	.....	12,180	.....	10,913	8,904
300	14,386	.....	.....	14,299	.....	.....	14,102	.....	13,420	.....	12,276	10,533
325	15,530	.....	.....	15,447	.....	.....	15,269	.....	14,642	.....	13,603	12,052
350	16678,	.....	.....	16,601	.....	.....	16,436	.....	15,850	.....	14,898	13,498
375	17,822	.....	.....	17,749	.....	.....	17,598	.....	17,054	.....	16,170	14,889
400	18,966	.....	.....	18,902	.....	.....	18,715	.....	18,248	.....	17,424	16,244

Capacity, in Cubic Feet, of 16″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	3,467	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	6,471	5,662	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	9,361	8,644	6,541	4,622	.....	.....	.....	.....	.....	.....	.....	.....
40	11,834	11,325	9,800	8,736	7,303	.....	.....	.....	.....	.....	.....	.....
50	14,284	13,868	12,666	11,834	10,840	7,997	.....	.....	.....	.....	.....	.....
60	16,711	16,341	15,324	.....	13,868	11,787	8,644	.....	.....	.....	.....	.....
70	19,091	.....	17,913	.....	16,664	14,977	12,643	.....	.....	.....	.....	.....
80	21,449	.....	20,409	.....	19,346	17,913	15,994	.....	.....	.....	.....	.....
90	23,830	.....	22,882	.....	21,934	20,663	19,068	12,481	.....	.....	.....	.....
100	26,187	.....	25,309	.....	24,384	23,113	21,934	16,549	.....	.....	.....	.....
125	32,035	.....	.....	31,018	.....	29,747	28,660	24,777	18,444	.....	.....	.....
150	37,860	.....	.....	37,005	.....	35,964	35,063	31,966	27,343	24,731	.....	.....
175	43,661	.....	.....	42,922	.....	.....	41,257	38,669	34,901	29,677	21,773	.....
200	49,486	.....	.....	48,839	.....	.....	47,359	45,141	41,997	37,721	31,873	.....
225	55,264	.....	.....	54,548	.....	.....	53,392	.....	48,538	45,048	40,217	24,500
250	61,066	.....	.....	60,557	.....	.....	59.379	.....	55,195	52,005	47,937	35,803
275	66,867	.....	.....	66,382	.....	.....	65,319	.....	61,528	.....	55,126	44,979
300	72,669	.....	.....	72,230	.....	.....	71,237	.....	67,792	.....	62,014	53,207
325	78,477	.....	.....	78,078	.....	.....	77,130	.....	73,963	.....	68,717	60,881
350	84,249	.....	.....	83,856	.....	.....	83,024	.....	80,065	.....	75,258	68,185
375	90,027	.....	.....	89,658	.....	.....	88,895	.....	86,144	.....	81,683	75,211
400	95,806	.....	.....	95,482	.....	.....	94,535	.....	92,177	.....	88,016	82,053

Above table based on outside diameter of 16-inch pipe, or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 16″ Pipe Line 30 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,827	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	5,277	4,618	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	7,634	7,049	5,334	3,769	.....	.....	.....	.....	.....	.....	.....	.....
40	9,651	9,236	7,992	7,125	5,956	.....	.....	.....	.....	.....	.....	.....
50	11,649	11,309	10,329	9,651	8,840	6,521	.....	.....	.....	.....	.....	.....
60	13,628	13,320	12,497	.....	11,309	9,613	7,049	.....	.....	.....	.....	.....
70	15,569	.....	14,608	.....	13,590	12,214	10,310	.....	.....	.....	.....	.....
80	17,492	.....	16,644	.....	15,777	14,608	13,043	.....	.....	.....	.....	.....
90	19,434	.....	18,661	.....	17,888	16,851	15,551	10,178	.....	.....	.....	.....
100	21,356	.....	20,640	.....	19,886	18,849	17,888	13,496	.....	.....	.....	.....
125	26,125	.....	.....	25,296	.....	24,259	23,373	20,206	15,042	.....	.....	.....
150	30,875	.....	.....	30,178	.....	29,330	28,594	26,069	22,299	20,169	.....	.....
175	35,607	.....	.....	35,003	.....	.....	33,646	31,535	28,463	24,203	17,756	.....
200	40,357	.....	.....	39,829	.....	.....	38,623	36,813	34,249	30,762	25,993	.....
225	45,069	.....	.....	44,485	.....	.....	43,542	.....	39,584	36,738	32,798	19,980
250	49,800	.....	.....	49,386	.....	.....	48,424	.....	45,013	42,411	39,094	29,198
275	54,532	.....	.....	54,136	.....	.....	53,269	.....	50,177	.....	44,956	36,681
300	59,263	.....	.....	58,905	.....	.....	58,094	.....	55,286	.....	50,573	43,392
325	63,975	.....	.....	63,674	.....	.....	62,901	.....	60,319	.....	56,040	49,650
350	68,707	.....	.....	68,386	.....	.....	67,708	.....	65,295	.....	61,374	55,606
375	73,419	.....	.....	73,117	.....	.....	72,495	.....	70,252	.....	66,614	61,336
400	78,132	.....	.....	77,868	.....	.....	77,095	.....	75,172	.....	71,779	66,916

Above table based on outside diameter of 16-inch pipe or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 16″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,192	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	4,092	3,581	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	5,919	5,466	4,136	2,923	.....	.....	.....	.....	.....	.....	.....	.....
40	7,483	7,162	6,197	5,525	4,618	.....	.....	.....	.....	.....	.....	.....
50	9,032	8,769	8,009	7,483	6,855	5,057	.....	.....	.....	.....	.....	.....
60	10,567	10,333	9,690	.....	8,769	7,454	5,466	.....	.....	.....	.....	.....
70	12,073	.....	11,327	.....	10,538	9,471	7,995	.....	.....	.....	.....	.....
80	13,564	.....	12,906	.....	12,234	11,327	10,114	.....	.....	.....	.....	.....
90	15,069	.....	14,470	.....	13,871	13,067	12,058	7,892	.....	.....	.....	.....
100	16,560	.....	16,005	.....	15,420	14,616	13,871	10,465	.....	.....	.....	.....
125	20,258	.....	.....	19,615	.....	18,811	18,124	15,668	11,663	.....	.....	.....
150	23,941	.....	.....	23,401	.....	22,743	22,173	20,214	17,291	15,639	.....	.....
175	27,610	.....	.....	27,142	.....	.....	26,090	24,453	22,070	18,767	13,768	.....
200	31,293	.....	.....	30,884	.....	.....	29,949	28,546	26,558	23,854	20,156	.....
225	34,948	.....	.....	34,494	.....	.....	33,764	.....	30,694	28,487	25,432	15,493
250	38,616	.....	.....	38,295	.....	.....	37,549	.....	34,904	32,887	30,314	22,640
275	42,285	.....	.....	41,978	.....	.....	41,306	.....	38,909	.....	34,860	28,443
300	45,954	.....	.....	45,676	.....	.....	45,048	.....	42,870	.....	39,216	33,647
325	49,608	.....	.....	49,374	.....	.....	48,775	.....	46,772	.....	43,454	38,499
350	53,277	.....	.....	53,028	.....	.....	52,502	.....	50,631	.....	47,591	43,118
375	56,931	.....	.....	56,697	.....	.....	56,215	.....	54,475	.....	51,654	47,562
400	60,585	.....	.....	60,380	.....	.....	59,871	.....	58,290	.....	55,659	51,888

Above table based on outside diameter of 16-inch pipe or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 16″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,549	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,892	2,531	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,184	3,864	2,923	2,066	.....	.....	.....	.....	.....	.....	.....	.....
40	5,289	5,062	4,380	3,905	3,264	.....	.....	.....	.....	.....	.....	.....
50	6,385	6,199	5,661	5,289	4,845	3,574	.....	.....	.....	.....	.....	.....
60	7,470	7,304	6,850	.....	6,199	5,269	3,864	.....	.....	.....	.....	.....
70	8,534	.....	8,007	.....	7,449	6,695	5,651	.....	.....	.....	.....	.....
80	9,588	.....	9,123	.....	8,647	8,007	7,149	.....	.....	.....	.....	.....
90	10,652	.....	10,228	.....	9,805	9,236	8,523	5,579	.....	.....	.....	.....
100	11,706	.....	11,313	.....	10,900	10,332	9,805	7,397	.....	.....	.....	.....
125	14,320	.....	.....	13,865	.....	13,297	12,811	11,075	8,244	.....	.....	.....
150	16,923	.....	.....	16,541	.....	16,076	15,673	14,289	12,222	11,055	.....	.....
175	19,517	.....	.....	19,186	.....	.....	18,442	17,285	15,601	13,266	9,732	.....
200	22,120	.....	.....	21,831	.....	.....	21,170	20,178	18,773	16,861	14,247	.....
225	24,703	.....	.....	24,383	.....	.....	23,866	.....	21,697	20,137	17,977	10,951
250	27,297	.....	.....	27,069	.....	.....	26,542	.....	24,672	23,247	21,428	16,004
275	29,890	.....	.....	29,673	.....	.....	29,198	.....	27,503	.....	24,641	20,106
300	32,483	.....	.....	32,287	.....	.....	31,843	.....	30,303	.....	27,720	23,784
325	35,066	.....	.....	34,901	.....	.....	34,477	.....	33,062	.....	30,717	27,214
350	37,660	.....	.....	37,484	.....	.....	37,112	.....	35,790	.....	33,640	30,479
375	40,243	.....	.....	40,077	.....	.....	39,736	.....	38,507	.....	36,513	33,620
400	42,826	.....	.....	42,681	.....	.....	42,257	.....	41,204	.....	39,344	36,678

Above table based on outside diameter of 16-inch pipe or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 16″ Pipe Line 150 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,265	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,361	2,066	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	3,416	3,154	2,387	1,687	.....	.....	.....	.....	.....	.....	.....	.....
40	4,319	4,133	3,576	3,188	2,665	.....	.....	.....	.....	.....	.....	.....
50	5,213	5,061	4,622	4,319	3,956	2,918	.....	.....	.....	.....	.....	.....
60	6,099	5,964	5,592	.....	5,061	4,302	3,154	.....	.....	.....	.....	.....
70	6,967	.....	6,537	.....	6,082	5,466	4,614	.....	.....	.....	.....	.....
80	7,828	.....	7,448	.....	7,060	6,537	5,837	.....	.....	.....	.....	.....
90	8,697	.....	8,351	.....	8,005	7,541	6,959	4,555	.....	.....	.....	.....
100	9,557	.....	9,237	.....	8,899	8,435	8,005	6,039	.....	.....	.....	.....
125	11,691	.....	.....	11,320	.....	10,856	10,460	9,043	6,731	.....	.....	.....
150	13,817	.....	.....	13,505	.....	13,125	12,796	11,666	9,979	9,026	.....	.....
175	15,935	.....	.....	15,665	.....	.....	15,057	14,112	12,737	10,831	7,946	.....
200	18,060	.....	.....	17,824	.....	.....	17,284	16,474	15,327	13,767	11,632	.....
225	20,169	.....	.....	19,908	.....	.....	19,486	.....	17,714	16,441	14,678	8,941
250	22,287	.....	.....	22,101	.....	.....	21,671	.....	20,144	18,980	17,495	13,066
275	24,404	.....	.....	24,227	.....	.....	23,839	.....	22,455	.....	20,119	16,415
300	26,521	.....	.....	26,361	.....	.....	25,998	.....	24,741	.....	22,632	19,418
325	28,630	.....	.....	28,495	.....	.....	28,149	.....	26,994	.....	25,079	22,219
350	30,748	.....	.....	30,604	.....	.....	30,301	.....	29,221	.....	27,466	24,885
375	32,857	.....	.....	32,722	.....	.....	32,443	.....	31,439	.....	29,811	27,449
400	34,965	.....	.....	34,847	.....	.....	34,502	.....	33,641	.....	32,123	29,946

Above table based on outside diameter of 16-inch pipe or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 16″ Pipe Line 200 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,093	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,040	1,785	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	2,951	2,725	2,062	1,457	.....	.....	.....	.....	.....	.....	.....	.....
40	3,731	3,570	3,089	2,754	2,302	.....	.....	.....	.....	.....	.....	.....
50	4,503	4,372	3,993	3,731	3,417	2,521	.....	.....	.....	.....	.....	.....
60	5,269	5,152	4,831	.....	4,372	3,716	2,725	.....	.....	.....	.....	.....
70	6,019	.....	5,647	.....	5,254	4,722	3,986	.....	.....	.....	.....	.....
80	6,762	.....	6,435	.....	6,099	5,647	5,043	.....	.....	.....	.....	.....
90	7,513	.....	7,214	.....	6,916	6,515	6,012	3,935	.....	.....	.....	.....
100	8,256	.....	7,980	.....	7,688	7,287	6,916	5,217	.....	.....	.....	.....
125	10,100	.....	.....	9,780	.....	9,379	9,036	7,812	5,815	.....	.....	.....
150	11,937	.....	.....	11,667	.....	11,339	11,055	10,078	8,621	7,797	.....	.....
175	13,766	.....	.....	13,533	.....	.....	13,008	12,192	11,004	9,357	6,865	.....
200	15,602	.....	.....	15,398	.....	.....	14,932	14,232	13,241	11,893	10,049	.....
225	17,424	.....	.....	17,198	.....	.....	16,834	.....	15,304	14,203	12,680	7,724
250	19,254	.....	.....	19,093	.....	.....	18,722	.....	17,403	16,397	15,114	11,288
275	21,083	.....	.....	20,930	.....	.....	20,595	.....	19,399	.....	17,381	14,181
300	22,912	.....	.....	22,774	.....	.....	22,460	.....	21,374	.....	19,552	16,776
325	24,734	.....	.....	24,617	.....	.....	24,319	.....	23,320	.....	21,666	19,195
350	26,563	.....	.....	26,439	.....	.....	26,177	.....	25,244	.....	23,728	21,498
375	28,385	.....	.....	28,268	.....	.....	28,028	.....	27,161	.....	25,754	23,714
400	30,207	.....	.....	30,105	.....	.....	29,806	.....	29,063	.....	27,751	25,871

Above table based on outside diameter of 16-inch pipe or inside diameter of 15¼ inches.

Capacity, in Cubic Feet, of 18″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	4,769	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	8,902	7,789	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	12,877	11,891	8,998	6,359	.....	.....	.....	.....	.....	.....	.....	.....
40	16,279	15,579	13,481	12,018	10,047	.....	.....	.....	.....	.....	.....	.....
50	19,649	19,077	17,423	16,279	14,912	11,001	.....	.....	.....	.....	.....	.....
60	22,988	22,479	21,080	.....	19,077	16,215	11,891	.....	.....	.....	.....	.....
70	26,263	.....	24,641	.....	22,924	20,603	17,392	.....	.....	.....	.....	.....
80	29,506	.....	28,075	.....	26,612	24,641	22,002	.....	.....	.....	.....	.....
90	32,781	.....	31,477	.....	30,173	28,425	26,231	17,169	.....	.....	.....	.....
100	36,024	.....	34,816	.....	33,544	31,795	30,173	22,765	.....	.....	.....	.....
125	44,068	.....	.....	42,669	.....	40,920	39,426	34,084	25,372	.....	.....	.....
150	52,081	.....	.....	50,904	.....	49,473	48,233	43,973	37,614	34,021	.....	.....
175	60,061	.....	.....	59,044	.....	.....	56,754	53,193	48,011	40,825	29,951	.....
200	68,074	.....	.....	67,183	.....	.....	65,148	62,096	57,772	51,890	43,845	.....
225	76,023	.....	.....	75,037	.....	.....	73,447	.....	66,770	61,969	55,324	33,703
250	84,003	.....	.....	83,304	.....	.....	81,682	.....	75,927	71,539	65,943	49,251
275	91,984	.....	.....	91,316	.....	.....	89,854	.....	84,639	.....	75,832	61,874
300	99,965	.....	.....	99,360	.....	.....	97,993	.....	93,256	.....	85,307	73,193
325	107,913	.....	.....	107,405	.....	.....	106,101	.....	101,745	.....	94,528	83,749
350	115,894	.....	.....	115,354	.....	.....	114,209	.....	110,139	.....	103,526	93,796
375	123,843	.....	.....	123,334	.....	.....	122,285	.....	118,501	.....	112,365	103,462
400	131,792	.....	.....	131,347	.....	.....	130,043	.....	126,800	.....	121,077	112,874

Above table based on outside diameter of 18-inch pipe or inside diameter of 17¼ inches.

Capacity, in Cubic Feet, of 18″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	3,015	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	5,629	4,926	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	8,143	7,519	5,690	4,021	.....	.....	.....	.....	.....	.....	.....	.....
40	10,295	9,852	8,525	7,600	6,353	.....	.....	.....	.....	.....	.....	.....
50	12,425	12,063	11,018	10,294	9,429	6,956	.....	.....	.....	.....	.....	.....
60	14,537	14,215	13,330	.....	12,063	10,254	7,519	.....	.....	.....	.....	.....
70	16,608	.....	15,582	.....	11,496	13,029	10,998	.....	.....	.....	.....	.....
80	18,658	.....	17,754	.....	16,829	15,582	13,913	.....	.....	.....	.....	.....
90	20,729	.....	19,905	.....	19,081	17,975	16,587	10,857	.....	.....	.....	.....
100	22,780	.....	22,016	.....	21,212	20,106	19,081	14,396	.....	.....	.....	.....
125	27,867	.....	.....	26,983	.....	25,877	24,932	21,554	16,045	.....	.....	.....
150	32,934	.....	.....	32,190	.....	31,285	30,501	27,807	23,786	21,514	.....	.....
175	37,981	.....	.....	37,337	.....	.....	35,890	33,638	30,360	25,816	18,940	.....
200	43,048	.....	.....	42,485	.....	.....	41,198	39,268	36,533	32,813	27,727	.....
225	48,074	.....	.....	47,451	.....	.....	46,446	.....	42,223	39,187	34,985	21,312
250	53,121	.....	.....	52,679	.....	.....	51,653	.....	48,014	45,239	41,701	31,145
275	58,168	.....	.....	57,746	.....	.....	56,821	.....	53,523	.....	47,954	39,127
300	63,215	.....	.....	62,833	.....	.....	61,968	.....	58,972	.....	53,946	46,285
325	68,241	.....	.....	67,920	.....	.....	67,095	.....	64,341	.....	59,776	52,960
350	73,288	.....	.....	72,946	.....	.....	72,222	.....	69,649	.....	65,467	59,314
375	78,315	.....	.....	77,993	.....	.....	77,329	.....	74,937	.....	71,056	65,426
400	83,341	.....	.....	83,060	.....	.....	82,235	.....	80,185	.....	76,365	71,378

Capacity, in Cubic Feet, of 18″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,131	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,979	3,482	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	5,756	5,315	4,022	2,842	.....	.....	.....	.....	.....	.....	.....	.....
40	7,276	6,964	6,026	5,372	4,491	.....	.....	.....	.....	.....	.....	.....
50	8,783	8,527	7,788	7,276	6,665	4,917	.....	.....	.....	.....	.....	.....
60	10,275	10,048	9,423	.....	8,527	7,248	5,315	.....	.....	.....	.....	.....
70	11,739	.....	11,014	.....	10,247	9,209	7,774	.....	.....	.....	.....	.....
80	13,189	.....	12,549	.....	1,1896	11,014	9,835	.....	.....	.....	.....	.....
90	14,653	.....	14,070	.....	13,487	12,706	11,725	7,674	.....	.....	.....	.....
100	16,103	.....	15,563	.....	14,994	14,212	13,487	10,176	.....	.....	.....	.....
125	19,698	.....	.....	19,073	.....	18,291	17,623	15,236	11,341	.....	.....	.....
150	23,280	.....	.....	22,754	.....	22,115	21,560	19,656	16,813	15,207	.....	.....
175	26,847	.....	.....	26,393	.....	.....	25,369	23,778	21,461	18,249	13,388	.....
200	30,429	.....	.....	30,031	.....	.....	29,122	27,757	25,824	23,195	19,599	.....
225	33,982	.....	.....	33,542	.....	.....	32,831	.....	29,846	27,700	24,730	15,065
250	37,550	.....	.....	37,237	.....	.....	36,512	.....	33,940	31,978	29,477	22,015
275	41,117	.....	.....	40,819	.....	.....	40,165	.....	37,834	.....	33,897	27,658
300	44,685	.....	.....	44,415	.....	.....	43,803	.....	41,686	.....	38,132	32,717
325	48,238	.....	.....	48,010	.....	.....	47,428	.....	45,480	.....	42,254	37,436
350	51,805	.....	.....	51,564	.....	.....	51,052	.....	49,233	.....	46,276	41,927
375	55,358	.....	.....	55,131	.....	.....	54,662	.....	52,971	.....	50,228	46,248
400	58,912	.....	.....	58,713	.....	.....	58,130	.....	56,680	.....	54,122	50,455

Above table based on outside diameter of 18-inch pipe or inside diameter of 17¼ inches.

Capacity, in Cubic Feet, of 18″ Pipe Line 150 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,740	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,249	2,843	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,699	4,340	3,284	2,320	.....	.....	.....	.....	.....	.....	.....	.....
40	5,941	5,686	4,920	4,386	3,666	.....	.....	.....	.....	.....	.....	.....
50	7,171	6,962	6,359	5,941	5,442	4,015	.....	.....	.....	.....	.....	.....
60	8,389	8,204	7,693	.....	6,962	5,918	4,340	.....	.....	.....	.....	.....
70	9,585	.....	8,993	.....	8,366	7,519	6,347	.....	.....	.....	.....	.....
80	10,768	.....	10,246	.....	9,712	8,993	8,030	.....	.....	.....	.....	.....
90	11,964	.....	11,488	.....	11,012	10,374	9,573	6,266	.....	.....	.....	.....
100	13,147	.....	12,706	.....	12,242	11,604	11,012	8,308	.....	.....	.....	.....
125	16,083	.....	.....	15,630	.....	14,934	14,389	12,439	9,260	.....	.....	.....
150	19,007	.....	.....	18,578	.....	18,056	17,603	16,048	13,727	12,416	.....	.....
175	21,920	.....	.....	21,549	.....	.....	20,713	19,413	17,522	14,899	10,931	.....
200	24,844	.....	.....	24,519	.....	.....	23,777	22,663	21,085	18,938	16,002	.....
225	27,745	.....	.....	27,386	.....	.....	26,805	.....	24,369	22,616	20,191	12,300
250	30,658	.....	.....	30,403	.....	.....	29,811	.....	27,711	26,109	24,067	17,975
275	33,571	.....	.....	33,327	.....	.....	32,793	.....	30,890	.....	27,676	22,581
300	36,483	.....	.....	36,263	.....	.....	35,764	.....	34,035	.....	31,134	26,713
325	39,384	.....	.....	39,199	.....	.....	38,723	.....	37,133	.....	34,499	30,565
350	42,297	.....	.....	42,100	.....	.....	41,682	.....	40,197	.....	37,783	34,232
375	45,198	.....	.....	45,013	.....	.....	44,630	.....	43,249	.....	41,009	37,760
400	48,099	.....	.....	47,937	.....	.....	47,461	.....	46,277	.....	44,189	41,195

Above table based on outside diameter of 18-inch pipe or inside diameter of 17¼ inches.

Capacity, in Cubic Feet, of 18″ Pipe Line 200 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,503	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	2,807	2,456	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,060	3,749	2,837	2,005	.....	.....	.....	.....	.....	.....	.....	.....
40	5,132	4,912	4,250	3,789	3,167	.....	.....	.....	.....	.....	.....	.....
50	6,195	6,015	5,493	5,132	4,701	3,468	.....	.....	.....	.....	.....	.....
60	7,248	7,087	6,646	.....	6,015	5,112	3,749	.....	.....	.....	.....	.....
70	8,280	.....	7,769	.....	7,228	6,496	5,483	.....	.....	.....	.....	.....
80	9,303	.....	8,852	.....	8,391	7,769	6,937	.....	.....	.....	.....	.....
90	10,335	.....	9,924	.....	9,513	8,962	8,270	5,413	.....	.....	.....	.....
100	11,358	.....	10,977	.....	10,576	10,025	9,513	7,177	.....	.....	.....	.....
125	13,894	.....	.....	13,453	.....	12,902	12,431	10,746	8,000	.....	.....	.....
150	16,421	.....	.....	16,050	.....	15,599	15,208	13,864	11,859	10,726	.....	.....
175	18,937	.....	.....	18,616	.....	.....	17,894	16,771	15,137	12,872	9,443	.....
200	21,463	.....	.....	21,183	.....	.....	20,541	19,579	18,215	16,360	13,824	.....
225	23,970	.....	.....	23,659	.....	.....	23,157	.....	21,052	19,538	17,443	10,626
250	26,486	.....	.....	26,265	.....	.....	25,574	.....	23,939	22,556	20,792	15,528
275	29,002	.....	.....	28,792	.....	.....	28,330	.....	26,686	.....	23,909	19,508
300	31,518	.....	.....	31,328	.....	.....	30,897	.....	29,403	.....	26,897	23,077
325	34,025	.....	.....	33,864	.....	.....	33,453	.....	32,080	.....	29,804	26,406
350	36,541	.....	.....	36,371	.....	.....	36,010	.....	34,726	.....	32,641	29,574
375	39,047	.....	.....	38,887	.....	.....	38,556	.....	37,363	.....	35,428	32,621
400	41,554	.....	.....	41,413	.....	.....	41,002	.....	39,980	.....	38,175	35,589

Above table based on outside diameter of 18-inch pipe or inside diameter of 17¼ inches.

Capacity, in Cubic Feet, of 18″ Pipe Line 250 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,347	....	....	....	....	....	....	....	....	....	....	....
20	2,514	2,200	....	....	....	....	....	....	....	....	....	....
30	3,637	3,359	2,541	1,796	....	....	....	....	....	....	....	....
40	4,598	4,401	3,808	3,395	2,838	....	....	....	....	....	....	....
50	5,550	5,389	4,921	4,598	4,212	3,107	....	....	....	....	....	....
60	6,493	6,350	5,954	....	5,389	4,580	3,359	....	....	....	....	....
70	7,418	....	6,960	....	6,475	5,820	4,912	....	....	....	....	....
80	8,335	....	7,930	....	7,517	6,960	6,215	....	....	....	....	....
90	9,260	....	8,891	....	8,523	8,029	7,409	4,850	....	....	....	....
100	10,176	....	9,834	....	9,475	8,981	8,523	6,430	....	....	....	....
125	12,448	....	....	12,053	....	11,559	11,137	9,628	7,167	....	....	....
150	14,712	....	....	14,379	....	13,975	13,625	12,421	10,625	9,610	....	....
175	16,966	....	....	16,679	....	....	16,032	15,026	13,562	11,532	8,460	....
200	19,229	....	....	18,978	....	....	18,403	17,541	16,319	14,658	12,385	....
225	21,475	....	....	21,196	....	....	20,747	....	18,861	17,505	15,628	9,520
250	23,729	....	....	23,532	....	....	23,073	....	21,448	20,208	18,628	13,912
275	25,984	....	....	25,795	....	....	25,382	....	23,909	....	21,421	17,478
300	28,238	....	....	28,067	....	....	27,681	....	26,343	....	24,097	20,675
325	30,483	....	....	30,340	....	....	29,971	....	28,741	....	26,702	23,657
350	32,738	....	....	32,585	....	....	32,262	....	31,112	....	29,244	26,496
375	34,983	....	....	34,840	....	....	34,543	....	33,474	....	31,741	29,226
400	37,229	....	....	37,103	....	....	36,735	....	35,819	....	34,202	31,885

Above table based on outside diameter of 18-inch pipe or inside diameter of 17¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 20 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	6,291	....	....	....	....	....	....	....	....	....	....	....
20	11,744	10,276	....	....	....	....	....	....	....	....	....	....
30	16,986	15,686	11,869	8,388	....	....	....	....	....	....	....	....
40	21,474	20,552	17,783	15,854	13,253	....	....	....	....	....	....	....
50	25,920	25,165	22,984	21,474	19,671	14,512	....	....	....	....	....	....
60	30,324	29,653	27,808	....	25,165	21,390	15,686	....	....	....	....	....
70	34,644	....	32,505	....	30,240	27,179	22,942	....	....	....	....	....
80	38,923	....	37,035	....	35,106	32,505	29,024	....	....	....	....	....
90	43,243	....	41,523	....	39,803	37,497	34,602	22,649	....	....	....	....
100	47,521	....	45,927	....	44,249	41,943	39,803	30,031	....	....	....	....
125	58,132	....	....	56,287	....	53,980	52,009	44,962	33,470	....	....	....
150	68,702	....	....	67,150	....	65,263	63,627	58,007	49,618	44,879	....	....
175	79,230	....	....	77,888	....	....	74,868	70,170	63,333	53,854	39,510	....
200	89,799	....	....	88,625	....	....	85,941	81,914	76,210	68,450	57,839	....
225	100,285	....	....	98,985	....	....	96,888	....	88,080	81,746	72,980	44,459
250	110,813	....	....	109,890	....	....	107,751	....	100,159	94,371	86,989	64,969
275	121,341	....	....	120,460	....	....	118,530	....	111,652	....	100,034	81,621
300	131,868	....	....	131,071	....	....	129,268	....	123,018	....	112,533	96,552
325	142,354	....	....	141,683	....	....	139,963	....	134,217	....	124,696	110,477
350	152,882	....	....	152,169	....	....	150,659	....	145,290	....	136,566	123,731
375	163,367	....	....	162,696	....	....	161,312	....	156,321	....	148,226	136,482
400	173,853	....	....	173,266	....	....	171,546	....	167,268	....	159,718	148,897

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 50 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	3,978											
20	7,426	6,498										
30	10,742	9,919	7,506	5,304								
40	13,580	12,996	11,246	10,025	8,381							
50	16,391	15,914	14,534	13,580	12,439	9,177						
60	19,176	18,752	17,585		15,914	13,527	9,919					
70	21,908		20,555		19,123	17,187	14,508					
80	24,613		23,420		22,200	20,555	18,354					
90	27,345		26,258		25,170	23,712	21,881	14,322				
100	30,051		29,043		27,982	26,523	25,170	18,990				
125	36,761			35,594		34,135	32,889	28,433	21,165			
150	43,445			42,464		41,270	40,236	36,682	31,377	28,380		
175	50,103			49,254			47,344	44,373	40,050	34,056	24,985	
200	56,787			56,044			54,346	51,800	48,193	43,286	36,576	
225	63,417			62,595			61,269		55,699	51,694	46,151	28,115
250	70,075			69,491			68,139		63,338	59,678	55,009	41,085
275	76,732			76,175			74,955		70,605		63,258	51,614
300	83,390			82,886			81,745		77,793		71,162	61,057
325	90,021			89,596			88,509		84,875		78,854	69,863
350	96,678			96,227			95,272		91,877		86,360	78,244
375	103,309			102,885			102,009		98,853		93,734	86,307
400	109,940			109,568			108,481		105,776		101,001	94,158

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 100 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,812											
20	5,249	4,593										
30	7,593	7,012	5,305	3,749								
40	9,599	9,186	7,949	7,087	5,924							
50	11,586	11,249	10,274	9,599	8,793	6,487						
60	13,555	13,255	12,430		11,249	9,561	7,012					
70	15,486		14,530		13,517	12,149	10,255					
80	17,398		16,555		15,692	14,530	12,974					
90	19,330		18,561		17,792	16,761	15,467	10,124				
100	21,242		20,529		19,779	18,748	17,792	13,424				
125	25,985			25,160		24,129	23,248	20,098	14,961			
150	30,710			30,016		29,173	28,441	25,929	22,179	20,061		
175	35,416			34,816			33,466	31,366	28,310	24,073	17,661	
200	40,141			39,616			38,416	36,616	34,066	30,598	25,854	
225	44,828			44,247			43,309		39,372	36,541	32,622	19,873
250	49,534			49,121			48,165		44,772	42,184	38,885	29,041
275	54,240			53,846			52,984		49,909		44,715	36,485
300	58,946			58,590			57,783		54,990		50,303	43,159
325	63,633			63,333			62,564		59,996		55,740	49,384
350	68,339			68,020			67,345		64,945		61,046	55,308
375	73,026			72,726			72,017		69,876		66,258	61,008
400	77,713			77,451			76,682		74,770		71,395	66,558

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 150 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	2,296	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	4,286	3,750	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	6,199	5,725	4,332	3,061	.....	.....	.....	.....	.....	.....	.....	.....
40	7,837	7,500	6,490	5,786	4,837	.....	.....	.....	.....	.....	.....	.....
50	9,460	9,184	8,388	7,837	7,179	5,296	.....	.....	.....	.....	.....	.....
60	11,067	10,822	10,149	.....	9,184	7,806	5,725	.....	.....	.....	.....	.....
70	12,644	.....	11,863	.....	11,036	9,919	8,373	.....	.....	.....	.....	.....
80	14,205	.....	13,516	.....	12,812	11,863	10,592	.....	.....	.....	.....	.....
90	15,782	.....	15,154	.....	14,527	13,685	12,628	8,266	.....	.....	.....	.....
100	17,343	.....	16,762	.....	16,149	15,307	14,527	10,960	.....	.....	.....	.....
125	21,216	.....	.....	20,543	.....	19,701	18,981	16,409	12,215	.....	.....	.....
150	25,074	.....	.....	24,507	.....	23,818	23,221	21,170	18,109	16,379	.....	.....
175	28,916	.....	.....	28,426	.....	.....	27,324	25,609	23,114	19,655	14,419	.....
200	32,773	.....	.....	32,345	.....	.....	31,365	29,896	27,814	24,982	21,109	.....
225	36,600	.....	.....	36,126	.....	.....	35,361	.....	32,146	29,834	26,635	16,226
250	40,443	.....	.....	40,106	.....	.....	39,325	.....	36,555	34,442	31,748	23,711
275	44,285	.....	.....	43,964	.....	.....	43,259	.....	40,749	.....	36,509	29,788
300	48,127	.....	.....	47,836	.....	.....	47,178	.....	44,897	.....	41,070	35,238
325	51,954	.....	.....	51,709	.....	.....	51,082	.....	48,984	.....	45,510	40,320
350	55,796	.....	.....	55,536	.....	.....	54,985	.....	53,026	.....	49,842	45,158
375	59,623	.....	.....	59,378	.....	.....	58,873	.....	57,052	.....	54,097	49,811
400	63,450	.....	.....	63,236	.....	.....	62,608	.....	61,047	.....	58,292	54,342

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 200 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,983	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,702	3,240	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	5,355	4,946	2,641	.....	.....	.....	.....	.....	.....	.....	.....	.....
40	6,770	6,480	5,607	4,998	4,178	.....	.....	.....	.....	.....	.....	.....
50	8,172	7,934	7,247	6,770	6,202	4,575	.....	.....	.....	.....	.....	.....
60	9,561	9,349	8,767	.....	7,934	6,744	4,946	.....	.....	.....	.....	.....
70	10,923	.....	10,249	.....	9,534	8,569	7,233	.....	.....	.....	.....	.....
80	12,272	.....	11,677	.....	11,068	10,249	9,151	.....	.....	.....	.....	.....
90	13,634	.....	13,092	.....	12,550	11,822	10,910	7,141	.....	.....	.....	.....
100	14,983	.....	14,480	.....	13,951	13,224	12,550	9,468	.....	.....	.....	.....
125	18,329	.....	.....	17,747	.....	17,020	16,398	14,176	10,553	.....	.....	.....
150	21,661	.....	.....	21,172	.....	20,577	20,061	18,289	15,644	14,150	.....	.....
175	24,981	.....	.....	24,558	.....	.....	23,605	22,124	19,969	16,980	12,457	.....
200	28,313	.....	.....	27,943	.....	.....	27,097	25,827	24,029	21,582	18,236	.....
225	31,620	.....	.....	31,210	.....	.....	30,548	.....	27,771	25,771	23,010	14,018
250	34,939	.....	.....	34,648	.....	.....	33,973	.....	31,580	29,755	27,427	20,484
275	38,258	.....	.....	37,981	.....	.....	37,372	.....	35,203	.....	31,540	25,735
300	41,578	.....	.....	41,326	.....	.....	40,758	.....	38,787	.....	35,481	30,443
325	44,884	.....	.....	44,672	.....	.....	44,130	.....	42,318	.....	39,316	34,833
350	48,203	.....	.....	47,978	.....	.....	47,502	.....	45,810	.....	43,059	39,012
375	51,509	.....	.....	51,298	.....	.....	50,861	.....	49,288	.....	46,735	43,032
400	54,815	.....	.....	54,630	.....	.....	54,088	.....	52,739	.....	50,359	46,946

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

Capacity, in Cubic Feet, of 20″ Pipe Line 250 Miles Long, for 24 Hours

All capacities given in thousands of cubic feet

Intake Press. Lb. per Sq. In.	Discharge Pressure in Lb.											
	5	10	20	25	30	40	50	75	100	125	150	200
10	1,777	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	3,317	2,902	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30	4,798	4,431	3,353	2,369	.....	.....	.....	.....	.....	.....	.....	.....
40	6,066	5,805	5,023	4,478	3,744	.....	.....	.....	.....	.....	.....	.....
50	7,322	7,108	6,492	6,066	5,556	4,099	.....	.....	.....	.....	.....	.....
60	8,566	8,376	7,855	.....	7,322	6,042	4,431	.....	.....	.....	.....	.....
70	9,786	.....	9,182	.....	8,542	7,677	6,480	.....	.....	.....	.....	.....
80	10,995	.....	10,461	.....	9,916	7,855	8,198	.....	.....	.....	.....	.....
90	12,215	.....	11,729	.....	11,243	10,592	9,775	6,398	.....	.....	.....	.....
100	13,424	.....	12,973	.....	12,499	11,848	11,243	8,483	.....	.....	.....	.....
125	16,421	.....	.....	15,900	.....	15,248	14,691	12,701	9,454	.....	.....	.....
150	19,407	.....	.....	18,968	.....	18,435	17,973	16,386	14,016	12,677	.....	.....
175	22,381	.....	.....	22,002	.....	.....	21 149	19,822	17,890	15,213	11,162	.....
200	25,366	.....	.....	25,035	.....	.....	24,276	23,139	21,528	19,336	16,338	.....
225	28,329	.....	.....	27,961	.....	.....	27,369	.....	24,881	23,092	20,615	12,559
250	31,302	.....	.....	31,042	.....	.....	30,438	.....	28,293	26,658	24,573	18,352
275	34,276	.....	.....	34,028	.....	.....	33,483	.....	31,539	.....	28,257	23,056
300	37,250	.....	.....	37,025	.....	.....	36,516	.....	34,750	.....	31,788	27,274
325	40,212	.....	.....	40,023	.....	.....	39,537	.....	37,914	.....	35,224	31,208
350	43,186	.....	.....	42,985	.....	.....	42,558	.....	41,042	.....	38,577	34,952
375	46,148	.....	.....	45,959	.....	.....	45,568	.....	44,158	.....	41,871	38,554
400	49,110	.....	.....	48,944	.....	.....	48,559	.....	47,250	.....	45,117	42,061

Above table based on outside diameter of 20-inch pipe or inside diameter of 19¼ inches.

PART SEVEN

COMPRESSION OF NATURAL GAS

Description—A great many people not directly connected with the gas business are under the impression that compressing natural gas consists of "pumping" air into a gas line. This is erroneous. A compressor outfit consists of steam or gas driven compressors, with all necessary cooling systems and appurtenances for taking gas from the field or incoming gas lines, at a low or natural pressure, compressing and delivering it at a higher pressure to outgoing lines, in order to overcome the friction in the line en route to the next compressing station or to the market.

If air were introduced into a gas line under pressure, there would be great liability of an explosion of the whole line, due to the air mixing with the gas and forming an explosive mixture found in a gas engine cylinder.

Object of Compressors—The distance of flow of natural gas from the gas well is limited by the "rock pressure" or natural pressure. The higher the "rock pressure," the greater the distance a certain quantity of gas will flow from the well in a certain sized pipe line.

The two illustrations following give a very comprehensive idea of the advantage of the compressor.

The first illustration shows the comparative size of pipe necessary to carry three million cubic feet of gas in twenty-four hours, one hundred miles, with and without the aid of a compressor.

An eighteen-inch pipe line will cost to lay, including pipe, from ten to twelve times as much as a six-inch pipe line.

Fig. Nos. 125 and 126 show the comparative lengths of two six-inch pipe lines, one being connected with a compressor and receiving its gas at 300-lb. pressure, and the

other receiving its gas from the field at a natural pressure of 25 lb., and both delivering three million cubic feet of gas per twenty-four hours at a 5 lb. discharge pressure.

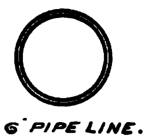


Fig. 123—With a compressor at the intake of 6" pipe line compressing gas to a pressure of 300 lb. and with 5 lb. at the discharge end it will require a 6" line.

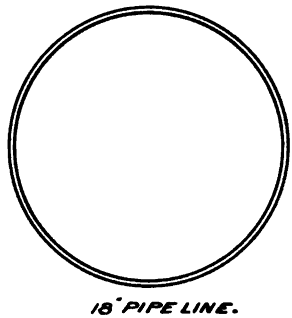


Fig. 124—Without a compressor and gas at 14 lb. pressure at the intake of line, with 5 lb. pressure at the discharge end it will require an 18 inch line.

When the natural pressure of gas in the field decreases to such an extent that it cannot be delivered at distant points without the employment of exceedingly large size lines, it is

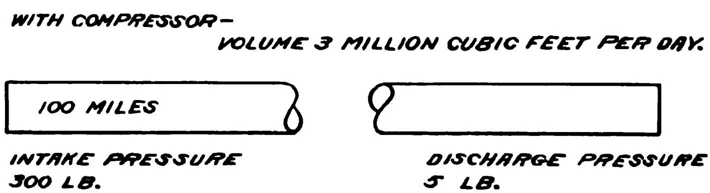


Fig. 125

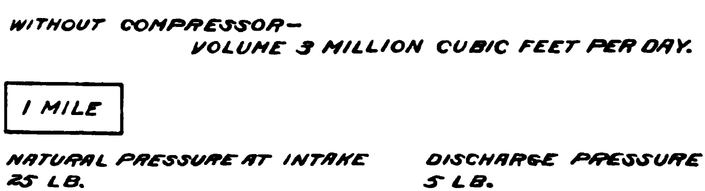


Fig. 126

necessary to install compressors to raise the pressure. These can be driven either by steam or gas engine, either direct connected or belt drive. They can also be driven by electric motor, in which case, however, alternating current induction motors should be used, in order not to have any sparks in the compressor station, which would be the case if direct current commutator motors were used. Belt or rope drive can be employed, but direct connected compressors are preferable unless the units are so small that it would entail too high a speed for economical operation. If gas engines are adopted, using natural gas for fuel, it is good practice to have them so

Fig. 127—HAULING A COMPRESSOR BED WITH A TRACTOR AND SEVERAL TEAMS OF HORSES

designed as to be capable of being converted into producer-gas engines in case the price of gas should rise to a point sufficient to warrant using coal in a gas producer. The advisability of this, however, depends upon the availability and cost of coal in the locality of the plant.

The capacity of compressor cylinders of different diameters, is shown in the following table, based on an actual volumetric efficiency of 80 per cent. This table assumes that

the intake pressure of the gas entering the compressor cylinder is at atmosphere and the measurement basis of the gas discharged from the compressor is also at atmosphere (14.4 pounds per square inch absolute).

TABLE No. 49

Diameter of Cylinder		Diameter of Cylinder		Diameter of Cylinder	
10	99	21	454	32	1060
11	121	22	499	33	1130
12	144	23	545	34	1197
13	171	24	595	35	1270
14	199	25	646	36	1342
15	231	26	698	37	1418
16	262	27	753	38	1498
17	295	28	810	39	1577
18	333	29	869	40	1660
19	370	30	930		
20	410	31	995		

The figures in Table No. 49 give the quantity of gas, in cubic feet per 24 hours, compressed by a cylinder of one inch stroke, running at one revolution per minute with intake pressure at 14.4 pounds per square inch absolute (equal to atmospheric pressure or 0 pounds gauge).

To ascertain the quantity of gas compressed by a cylinder of any diameter, running at a given number of revolutions per minute, with the intake at atmosphere, multiply the number corresponding to the diameter, taken from table, No. 49 by the length of the stroke in inches and the number of revolutions per minute. If the intake pressure is at any value other than atmosphere, multiply the quantity as obtained above by the fraction,

$$\frac{p + 14.4}{14.4}$$

where p is the actual intake pressure in the line in pounds per square inch gauge.

The power required to .compress natural gas depends upon the ratio of intake to discharge pressure in pounds per square inch absolute. Table No. 50 shows the indicated

TABLE No. 50—Indicated Horse Power on the Compressor Piston per Million Cubic Feet of Natural Gas per Day

Suction or Intake Pressure	Discharge Pressure, Pounds per Square Inch, Gauge																	
	50		60		70		80		90		100		125		150		175	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10 in. Vac.	111.3	107.0	123.0	114.0	133.7	121.6	144.3	128.2		133.8		139.0		150.0		159.6		168.0
5 in. Vac	96.0	95.8	105.7	103.0	115.1	110.5	124.0	116.0	132.8	121.0	141.3	126.2		137.8		146.4		154.6
0 Lb.	84.3		93.8	93.8	102.0	100.0	110.0	106.0	117.5	111.2	125.0	116.0	142.7	127.4		136.2		144.6
5 Lb.	67.0		75.3		82.8		89.5		96.0	95.8	102.2	100.2	116.8	110.2	130.3	120.0	143.5	127.8
10 Lb.	54.5		62.5		69.5		75.9		81.8		88.8		100.0	98.2	112.0	107.6	123.0	114.6
15 Lb.	44.6		52.5		59.0		65.4		71.0		76.3		88.0		98.5	97.6	108.3	105.6
20 Lb.			44.0		50.8		56.9		62.3		67.4		78.6		88.3		97.5	97.0
25 Lb.					43.8		49.5		54.8		59.6		71.0		80.1		88.8	
30 Lb.							43.4		48.7		53.2		64.1		73.3		81.7	
35 Lb.									42.9		48.0		58.1		67.3		75.1	
40 Lb.											42.5		53.0		62.0		69.9	
45 Lb.													48.5		57.0		65.0	
50 Lb.													44.0		52.9		60.5	
60 Lb.															45.1		52.9	
70 Lb.																	45.9	
80 Lb.																	40.2	
90 Lb.																		
100 Lb.																		
120 Lb.																		
140 Lb.																		
160 Lb.																		
180 Lb.																		
200 Lb.																		

Indicated Horse Power on the Compressor Piston per Million Cubic Feet of Natural Gas per Day—*Continued*

Suction or Intake Pressure	Discharge Pressure, Pounds Per Square Inch, Gauge																	
	200		225		250		275		300		325		350		375		400	
	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage	One Stage	Two Stage
10 in. Vac.		176.0		182.2		189.0		194.6		200.0		206.0		210.4		215.4		220.0
5 in. Vac.		162.2		168.6		175.0		180.2		185.8		190.4		195.6		200.0		204.0
0 Lb.		151.4		158.0		164.0		169.0		174.2		178.8		183.8		187.6		191.8
5 Lb.		134.5		141.0		146.0		151.6		156.6		160.6		165.2		168.8		172.6
10 Lb.	133.8	122.0	144.1	128.0		133.6		138.6		143.3		147.6		151.8		156.0		158.6
15 Lb.	118.0	111.6	126.9	117.4	135.8	123.0	144.4	128.2		132.6		137.0		141.0		144.6		148.2
20 Lb.	106.0	103.4	114.2	109.4	122.1	114.0	129.9	119.4	137.4	124.0	144.8	128.2		132.2		135.8		139.6
25 Lb.	96.8	96.0	104.2	102.0	111.4	107.2	118.5	112.0	125.2	116.2	132.0	120.6	138.3	124.6	144.9	128.4		131.8
30 Lb.	89.1		96.1	95.6	103.0	100.6	109.4	106.0	115.8	110.0	121.9	114.0	127.5	118.0	133.6	121.8	139.3	125.6
35 Lb.	82.5		89.3		95.8	95.4	101.7	100.0	107.7	104.4	113.3	108.4	118.7	112.4	124.1	116.0	129.0	119.6
40 Lb.	76.9		83.3		89.4		95.2	94.8	100.7	99.0	106.1	103.6	111.2	107.2	116.3	110.2	121.2	114.0
45 Lb.	71.8		78.2		84.2		89.7		95.0	94.6	100.0	98.6	104.9	102.4	109.8	106.2	114.3	109.6
50 Lb.	67.3		73.5		79.1		84.7		89.7		94.8	94.6	99.3	98.0	103.9	101.8	108.2	105.4
60 Lb.	59.1		65.3		71.1		76.2		81.0		85.5		90.0		94.1	94.0	98.2	97.6
70 Lb.	52.8		58.2		64.0		69.1		73.6		78.2		82.2		86.1		90.1	
80 Lb.	46.5		52.8		57.7		62.8		67.3		71.7		75.8		79.7		83.1	
90 Lb.	41.5		47.0		52.5		57.0		62.0		66.0		70.0		73.8		77.3	
100 Lb.			42.1		47.5		52.7		56.9		61.0		65.0		68.8		72.3	
120 Lb.							43.9		48.4		52.7		56.0		59.8		63.1	
140 Lb.									41.0		45.0		48.8		52.2		55.2	
160 Lb.													42.2		45.8		49.0	
180 Lb.															40.0		43.5	
200 Lb.																	38.1	

horse power required on the compressor piston to compress gas at the rate of 1,000,000 cubic feet per day, from various intake pressures to various discharge pressures. As will be seen from the table, when the range of pressures through which the gas is compressed becomes high, the power required is much less when two stage compression is adopted, than when the gas is compressed through a single stage. The values in the following table must be increased by ten per cent. to ascertain the brake horse power required from the engine. The power is directly proportional to the quantity of gas compressed.

In addition to the decreased power per million feet of gas required by two stage compression over single stage compression, a further advantage is obtained by the reduction of the temperature of the discharged gas. In fact, it is necessary to adopt two stage compression when necessary to compress through a wide range of pressures in order to keep the temperatures from becoming injuriously high. The temperature rise due to the compressing of gas depends upon the ratio of the absolute pressure of discharge to intake, and not upon their actual values. For instance, the temperature rise is as great in compressing from atmosphere to 60 pounds as from 60 pounds to 360 pounds. In order to obtain the benefits of two stage compression it is necessary to cool the gas after it leaves the first stage compressor and before entering the second stage. It is also advisable to cool it after leaving the high stage, for two reasons. First, this obviates injurious effects to sleeve couplings in the discharge line due to the high heat. Second, it condenses whatever liquid there may be thrown down by the gas due to its compression before these liquids have an opportunity to pass out into the main line, where they would freeze and plug the line. It is therefore necessary, in addition to coolers, to provide the system with proper drips.

When gas is compressed through a pressure range not greater than three compressions, it is not necessary to employ a very extensive cooling system.

Do not place a large capacity meter less than two miles ahead of a compressor, without providing an extra system of gas tanks or drips to absorb the vibration or throb of the piston.

Ample receiver or tank capacity should be provided on the high pressure line, located from 100 to 200 feet from the compressing plant, with a blow-off valve, so that the moisture and semi-solids, carried by the gas, may be dropped in cooling, trapped and blown off, and thus prevented from passing into the line.

In case of dirty gas, it is also important to provide a tank or receiver upon the intake main near the compressing plant, to trap out sand and solids to prevent their entrance into the compression cylinders.

When the intake line is operated below atmospheric pressure a by-pass can be arranged to cut off the tank and blow it out.

A relief valve should always be placed on the compressor discharge between the cylinder and the first gate, to protect the compressor in case it is started up with the discharge gate closed.

PART EIGHT

MEASUREMENT OF FLOWING GAS IN PIPE LINES.

THE ORIFICE METER

The first Orifice Meter was evolved from the old Pitot Tube or Pitot Meter, invented by Henry Pitot, some time during the year 1750. It was first used for measuring water in flowing streams, and only in recent years was the principle applied to the measurement of flowing gas in pipe lines. From this beginning came the orifice meter for measuring flowing gas in pipe lines. Since 1911, when the first orifice meter was placed in service on natural gas, it has been successfully used to measure other gases as well as for measuring steam and water. Without question it is becoming the Standard Meter for measurement of gas, air, and steam in large volumes and at high pressure.

Measuring by Orifice Meter is measuring by weight or impact. An Orifice Meter installation consists of an orifice placed in the pipe line either between two flanges or in a casting, a recording differential gauge with two pressure connections, one on each side of the orifice, and a static pressure gauge connected with the pipe line. The drop in pressure between the two sides of the orifice is recorded on the chart of the differential gauge and the static pressure either recorded on the same chart or a second chart. The greater the volume of gas flowing through the orifice the greater the differential. The coefficient for the orifice must be known in order to figure the volume of gas that passed the orifice in one hour (generally coefficients are given for one hour).

The formula to be applied to the chart readings is the same for the old Pitot Tube or Pitot Meter used centuries ago.

Hourly Coefficient $\sqrt{hp}$

h = height of water in inches or differential pressure.

p = absolute pressure (atmospheric pressure plus gauge pressure).

Fig. 129—AN ORIFICE METER INSTALLATION SHOWING DIFFERENTIAL GAUGES INSTALLED IN A HOUSE BUILT OVER A SERIES OF GAS LINES

The differential pressure is measured or recorded in inches of water pressure. The static pressure is recorded in pounds per square inch.

The hourly coefficient for any sized orifice is supplied by the factory.

The formula $\sqrt{hp}$ is worked out for all differential pressures from one to fifty inches differential, and from twenty-nine inches of mercury vacuum up to 500 lb. static pressure.

Measuring gas by Orifice Meter is carefully explained in detail with many necessary tables given in addition to a complete set of pressure extensions, in our hand book entitled, "Measurement of Gas by Orifice Meter," by the author. In this book the subject will only be given briefly with such data as is necessary in measuring high-pressure natural gas. In so doing, new tables or new material are used as far as possible.

During recent years the Orifice Meter has come into general use for measuring high-pressure natural gas, the gravity of which remains fairly constant. Its simplicity and accuracy recommend it for this particular character of work.

For measuring natural gas for factory use at a low pressure the Orifice Meter is well adapted, provided the pressure is high enough to permit the use of it.

The differential of the Orifice Meter ranges from two to three inches of water pressure up to 50 or 100 inches (according to whether a 50-inch or a 100-inch gauge is used) which is equivalent to nearly two or four pounds, whereas the proportional meter only has a differential at its maximum capacity of 4 to 4½ inches of water pressure, equivalent to about one-seventh of one pound.

Fig. 130—AN ORIFICE METER INSTALLATION IN WHICH A FIFTY-INCH DIFFERENTIAL GAUGE AND A BODY CASTING TO CARRY THE ORIFICE ARE USED

Fig. 131—ONE TYPE OF 100-INCH DIFFERENTIAL GAUGE

TABLE No. 51
FLANGE DIMENSIONS
250 LB. TEST

Pipe Size in Inches	Diameter Flange	Thickness	Diameter Bolt Circle	No. of Bolts	Size of Bolts
2	6½	⅞	5	4	⅝
2½	7½	1	5⅞	4	¾
3	8¼	1⅛	6⅝	8	⅝
3½	9	1 3/16	7¼	8	⅝
4	10	1¼	7⅞	8	¾
4½	10½	1 5/16	8½	8	¾
5	11	1⅜	9¼	8	¾
6	12½	1 7/16	10⅝	12	¾
7	14	1½	11⅞	12	⅞
8	15	1⅝	13	12	⅞
9	16	1¾	14	12	⅞
10	17½	1⅞	15¼	16	⅞
12	20	2	17¾	16	⅞
14	22½	2⅛	20	20	⅞
15	23½	2 3/16	21	20	1
16	25	2¼	22½	20	1
18	27	2⅜	24½	24	1
20	29½	2½	26¼	24	1⅛
22	31½	2⅝	28¾	28	1⅛
24	34	2¾	31¼	28	1⅛

* Adopted at a conference of manufacturers in 1901.

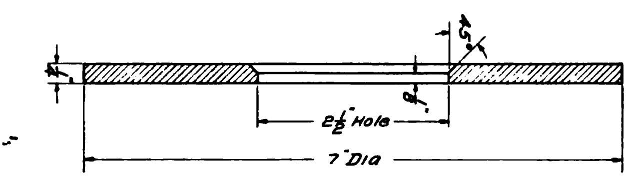


Fig. 132

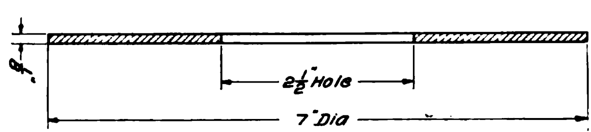


Fig. 133

SECTIONAL VIEWS OF THE BEVEL EDGE AND STRAIGHT EDGE TYPES OF FLANGE ORIFICES

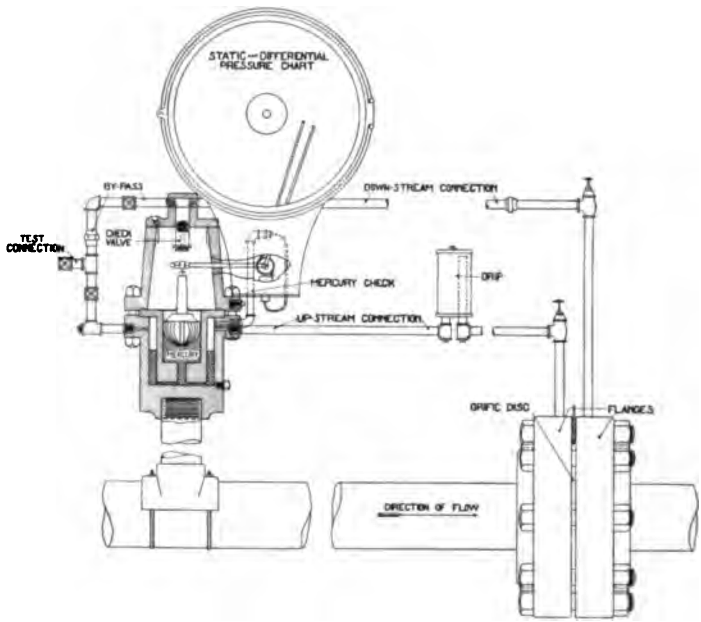


Fig. 134—ORIFICE METER SETTING IN WHICH PRESSURES ARE TAKEN AT THE FLANGE

Note by-pass on gauge where three valves are used.

TABLE No. 52
HOURLY COEFFICIENTS FOR THIN ORIFICES

Pressures taken 2½ diameters upstream and 8 diameters downstream.

Atmospheric Pressure 14.4. **Specific Gravity .6. Pressure Base 0.** Flowing and Storage Temperature 60 deg. fahr.

Diameter of Orifice	Diameter of Pipe Line			
	4 inch	6 inch	8 inch	10 inch
½	68.68	68.27	68.06	68.00
⅝	107.90	......	......	......
¾	156.3	154.4	153.8	153.4
⅞	214.6	......	......	......
1	282.9	276.7	274.6	273.7
1⅛	362.0	......	......	......
1¼	452.6	436.8	431.5	429.2
1⅜	555.3	......	......	......
1½	671.2	636.7	625.6	620.5
1⅝	802.8	......	......	......
1¾	953.0	879.1	858.5	848.8
1⅞	1123.4	......	......	......
2	1316.1	1167.2	1131.4	1151.1
2⅛	1535.4	......	......	......
2¼	1784.8	1509.3	1448.2	1421.2
2⅜	2079.5	......	......	......
2½	2396.3	1911.2	1808.9	1767.2
2⅝	2771.5	......	......	.....
2¾	3204.1	2390.0	2218.6	2155.9
2⅞	3692.5	......	......	......
3	4255.3	2952.7	2683.8	2588.3
3¼	......	3623.7	3208.3	3062.2
3½	......	4425.6	3809.1	3599.7
3¾	......	5379.3	4485.8	4187.1
4	......	6520.0	5254.4	4832.0
4¼	......	7880.0	6135.3	5546.1
4½	......	9499.4	7125.7	6337.3
4¾	......	......	8277.5	7208.5
5	......	......	9563.3	8173.0
5¼	......	......	11071.3	9248.6
5½	......	......	12789.7	10419.8
5¾	......	......	14725.7	11746.6
6	......	......	16952.1	13200.9
6¼	......	......	......	14822.1
6½	......	......	......	16634.3
6¾	......	......	......	18652.1
7	......	......	......	20909.1
7¼	......	......	......	23399.2
7½	......	......	......	26141.3

CORRECTING COEFFICIENTS

This is very important and should be fully understood by meter readers or caretakers as well as the office men reading the charts. Seldom will natural, casinghead, or coke oven gas carry the same specific gravity.

The correction for pressure base need only be made when the orifice meter is first installed. This should be done in accordance with the gas purchasing or selling contract.

Correcting Coefficient for Temperature Changes—In the past corrections have seldom been made on proportional meter readings even through an average change of 5 deg. fahr. means one per cent. It is generally conceded that temperatures would average around 60 deg. fahr. throughout the year. In measuring gas or air with an orifice meter it takes approximately ten degrees change in temperature to make one per cent. change in meter reading. Consequently, the effects of temperature changes on orifice meter readings is less by practically one-half than on proportional meter readings.

To change to another set of flowing and base or storage temperature conditions, use the following formula:

Where

C = Coefficient.

C' = Corrected Coefficient.

T_s = Absolute Storage or Base Temperature in deg. fahr.

T_f = Absolute Flowing or Observed Temperature in deg. fahr.

T_s' = New Absolute Storage or Base Temperature in deg. fahr.

T_f' = New Absolute Flowing or Observed Temperature in deg. fahr.

Formula is—

$$C' = C\frac{T_s'}{T_s}\sqrt{\frac{T_f}{T_f'}}$$

For example: Correct a coefficient of 500 from 60 deg. fahr. flowing and storage temperature to a flowing temperature of 40 deg. fahr. and a storage temperature of 50 deg. fahr.

$$C = 500. \qquad T_s' = 460 + 50.$$
$$T_s = 460 + 60. \qquad T_f' = 460 + 40.$$
$$T_f = 460 + 60.$$

$$C \frac{460 + 50}{460 + 60} \sqrt{\frac{460 + 60}{460 + 40}} =$$

$$C \frac{510}{520} \sqrt{\frac{520}{500}} = 500.0 = \text{Corrected coefficient.}$$

It will be noted that there is no change in the above coefficient by the above correction.

Correcting Coefficient for Change in Pressure Base—To correct for change of pressure base multiply the given air coefficient by

$$\frac{14.4}{14.4 + \text{pressure base}} = \text{corrected coefficient.}$$

Correcting Coefficient for Change in Specific Gravity—The specific gravity of the gas should be taken periodically, as it is liable to change. As gas wells grow old their gravity has a tendency to become higher. Unless the true specific gravity of the gas is known and the coefficient corrected for it, the orifice meter will not measure the gas accurately.

To correct a coefficient for change in specific gravity the formula is—

$$C' = C \sqrt{\frac{G_f}{G_x}}$$

Where

G_f = Specific gravity used in old coefficient.
G_x = True specific gravity of gas.
C = Old coefficient.
C' = Corrected coefficient.

TABLE No. 53—To Determine the Proper Size Orifice and Orifice Meter to Measure Different Volumes of Gas at a Specific Gravity of .6 at Various Pressures above 1 lb. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream

All Capacities Given in Thousands of Cubic Feet

Pressure Base, 14.41 lb. Flowing and Storage Temperature, 60 deg. fahr.

Volume per 24 Hours	Volume per Hour	Pressure in Pounds per Square Inch									
		1	25	50	75	100	150	200	250	300	400
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
100	4	4 x ¾	4 x ¾	4 x ¾	4 x ½	4 x ½	4 x ½	4 x ½	4 x ½	4 x ½	4 x ½
200	8	4x 1¼	4 x 1	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ½	4 x ½
300	12	4 x 1¼	4 x 1¼	4 x 1	4 x 1	4 x 1	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ¾
400	16	4 x 1½	4 x 1¼	4 x 1¼	4 x 1	4 x 1	4 x 1	4 x 1	4 x ¾	4 x ¾	4 x ¾
500	20	4 x 1¾	4 x 1½	4 x 1¼	4 x 1¼	4 x 1	4 x 1	4 x 1	4 x 1	4 x 1	4 x ¾
750	31	4 x 2	4 x 1¾	4 x 1½	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1	4 x 1	4 x 1
1,000	41	4 x 2¼	4 x 2	4 x 1¾	4 x 1½	4 x 1½	4 x 1½	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1¼
1,250	52	4 x 2½	4 x 2	4 x 1¾	4 x 1¾	4 x 1¾	4 x 1½	4 x 1½	4 x 1½	4 x 1¼	4 x 1¼
1,500	62	4 x 2½	4 x 2¼	4 x 2	4 x 2	4 x 1¾	4 x 1¾	4 x 1½	4 x 1½	4 x 1½	4 x 1¼
1,750	72	6 x 3	4 x 2½	4 x 2	4 x 2	4 x 2	4 x 1¾	4 x 1¾	4 x 1½	4 x 1½	4 x 1½
2,000	83	6 x 3½	4 x 2½	4 x 2¼	4 x 2	4 x 2	4 x 1¾	4 x 1¾	4 x 1¾	4 x 1½	4 x 1½
2,500	104	6 x 3½	6 x 3	4 x 2½	4 x 2¼	4 x 2¼	4 x 2	4 x 2	4 x 1¾	4 x 1¾	4 x 1¾
3,000	125	8 x 4	6 x 3	4 x 2½	4 x 2½	4 x 2¼	4 x 2¼	4 x 2	4 x 2	4 x 2	4 x 1¾
4,000	166	8 x 4½	6 x 3½	6 x 3	6 x 3	4 x 2½	4 x 2½	4 x 2¼	4 x 2¼	4 x 2¼	4 x 2
5,000	208	8 x 5	8 x 4	6 x 3½	6 x 3½	6 x 3	4 x 2½	4 x 2½	4 x 2½	4 x 2¼	4 x 2¼
6,000	250	8 x 5	8 x 4½	8 x 4	6 x 3½	6 x 3½	6 x 3	6 x 3	4 x 2½	4 x 2½	4 x 2¼
8,000	333	8 x 5½	8 x 5	8 x 4½	8 x 4	8 x 4	6 x 3½	6 x 3½	6 x 3	6 x 3	4 x 2½
10,000	416	10 x 6½	8 x 5½	8 x 5	8 x 4½	8 x 4½	8 x 4	6 x 3½	6 x 3½	6 x 3½	6 x 3

TABLE No. 54—To Determine the Proper Size Orifice and Orifice Meter to Measure Different Volumes of Gas of .6 Specific Gravity at Various Pressures Below 10 lb. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

All Capacities Given in Thousand of Cubic Feet

Vol. per 24 Hours	Vol. per Hour	10 lb.	0 Atmos.	Inches of Mercury Vacuum 5	10	15	20	25	27
		Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches	Size of Orifice in Inches
25	1	4 x ½	4 x ½	4 x ½	4 x ¾	4 x ¾	4 x ¾	4 x 1	4 x 1
50	2	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x 1	4 x 1	4 x 1¼
75	3	4 x ¾	4 x 1	4 x 1	4 x 1	4 x 1	4 x 1¼	4 x 1½	4 x 1½
100	4	4 x 1	4 x 1	4 x 1	4 x 1	4 x 1¼	4 x 1¼	4 x 1½	4 x 1¾
125	5	4 x 1	4 x 1	4 x 1	4 x 1¼	4 x 1¼	4 x 1½	4 x 1¾	4 x 2
150	6	4 x 1	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1½	4 x 1½	4 x 2	4 x 2
175	7	4 x 1	4 x 1¼	4 x 1¼	4 x 1½	4 x 1½	4 x 1¾	4 x 2	4 x 2¼
200	8	4 x 1¼	4 x 1¼	4 x 1½	4 x 1½	4 x 1½	4 x 1¾	4 x 2	4 x 2½
250	10	4 x 1¼	4 x 1½	4 x 1½	4 x 1¾	4 x 1¾	4 x 2	4 x 2½	4 x 2½
300	12	4 x 1½	4 x 1½	4 x 1¾	4 x 1¾	4 x 2	4 x 2	4 x 2½	4 x 2½
350	14	4 x 1½	4 x 1½	4 x 1¾	4 x 2	4 x 2	4 x 2	4 x 2½	6 x 3
400	16	4 x 1½	4 x 1½	4 x 2	4 x 2	4 x 2	4 x 2½	4 x 2½	6 x 3½
450	18	4 x 1¾	4 x 2	4 x 2	4 x 2	4 x 2½	4 x 2½	4 x 2½	6 x 3½
500	20	4 x 1¾	4 x 2	4 x 2	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½
600	25	4 x 2	4 x 2	4 x 2½	4 x 2½	4 x 2½	4 x 2½	6 x 3½	8 x 4
700	29	4 x 2	4 x 2½	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	8 x 4½
800	33	4 x 2	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	6 x 3½	8 x 4½
900	37	4 x 2½	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	8 x 4	8 x 4½
1000	41	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	6 x 3½	8 x 4½	8 x 5

TABLE No. 55—To Determine the Proper Size Orifice and Orifice Meter to Measure Different Volumes of Gas at a Specific Gravity of 1.0 at Various Pressures below 10 lb. Pressure. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

All Capacities Given in Thousands of Cubic Feet

Vol. per 24 Hours	Vol. per Hour	Pressure—10 lb.	0 lb.	• Inches of Mercury Vacuum					
				5	10	15	20	25	27
		Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
25	1	4 x ½	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x ¾	4 x 1	4 x 1
50	2	4 x ¾	4 x ¾	4 x 1	4 x 1	4 x 1	4 x 1	4 x 1¼	4 x 1½
75	3	4 x 1	4 x 1	4 x 1	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1½	4 x 2
100	4	4 x 1	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1½	4 x 1¾	4 x 2¼
125	5	4 x 1¼	4 x 1¼	4 x 1¼	4 x 1½	4 x 1½	4 x 1¾	4 x 2	4 x 2½
150	6	4 x 1¼	4 x 1½	4 x 1½	4 x 1½	4 x 1¾	4 x 1¾	4 x 2	4 x 2½
175	7	4 x 1¼	4 x 1½	4 x 1½	4 x 1½	4 x 2	4 x 2	4 x 2¼	6 x 3
200	8	4 x 1½	4 x 1½	4 x 1¾	4 x 1¾	4 x 2	4 x 2	4 x 2¼	6 x 3
250	10	4 x 1½	4 x 1¾	4 x 1¾	4 x 2	4 x 2	4 x 2¼	4 x 2½	6 x 3
300	12	4 x 1¾	4 x 1¾	4 x 2	4 x 2	4 x 2¼	4 x 2¼	6 x 3	6 x 3½
350	14	4 x 1¾	4 x 2	4 x 2	4 x 2¼	4 x 2¼	4 x 2½	6 x 3½	6 x 3½
400	16	4 x 2	4 x 2	4 x 2¼	4 x 2¼	4 x 2½	4 x 2½	6 x 3½	6 x 3½
450	18	4 x 2	4 x 2¼	4 x 2¼	4 x 2¼	4 x 2½	6 x 3	6 x 3½	8 x 4
500	20	4 x 2	4 x 2¼	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	8 x 4½
600	25	4 x 2¼	4 x 2½	4 x 2½	4 x 2½	6 x 3	6 x 3½	8 x 4	8 x 4½
700	29	4 x 2¼	4 x 2½	6 x 3	6 x 3	6 x 3½	6 x 3½	8 x 4½	8 x 5
800	33	4 x 2½	6 x 3	6 x 3	6 x 3½	6 x 3½	8 x 4	8 x 4½	8 x 5
900	37	4 x 2½	6 x 3	6 x 3½	6 x 3½	6 x 3½	8 x 4½	8 x 5	8 x 5½
1000	41	4 x 2½	6 x 3½	6 x 3½	6 x 3½	6 x 3½	8 x 4½	8 x 5	8 x 5½

TABLE No. 56—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 4 INCH ORIFICE METER

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 4″ Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
½″	6 18	7 22	8 25	9 30	12 39	14 46	16 52	19 62	22 71	25 79	27 86
⅝″	9 28	11 35	13 39	15 47	19 61	22 72	25 81	30 98	35 112	39 124	42 136
¾″	13 39	17 51	18 56	21 69	27 88	32 104	37 118	44 142	51 162	56 180	62 196
⅞″	18 56	23 71	26 78	30 95	38 121	45 143	51 162	61 194	70 221	78 246	84 268
1″	24 74	31 93	34 102	39 125	50 160	59 188	67 213	80 255	92 292	102 324	111 353
1⅛″	31 95	40 120	44 131	50 160	64 204	76 240	86 272	103 326	117 373	130 414	142 452
1¼″	39 119	50 150	54 164	62 200	80 255	95 301	107 340	129 408	147 466	163 518	178 565
1⅜″	48 146	61 183	67 200	77 245	99 313	116 369	132 418	158 501	180 572	200 635	219 693
1½″	58 176	74 222	81 243	93 296	120 379	141 447	160 505	191 606	218 692	242 769	265 839
1⅝″	70 211	88 265	97 291	112 354	143 453	168 534	191 604	229 725	261 827	290 918	316 1002

TABLE No. 56—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 4 INCH ORIFICE METER—Continued

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 4" Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
1¾"	83 250	105 315	115 345	132 420	169 537	200 632	226 715	271 858	310 980	344 1087	375 1187
1⅞"	97 292	123 368	135 403	155 494	199 631	235 744	266 842	319 1009	364 1152	404 1279	441 1395
2	115 346	145 435	160 477	182 579	234 741	275 873	312 987	374 1184	427 1352	474 1500	517 1637
2¼"	156 468	197 590	216 647	246 780	315 998	371 1176	420 1330	504 1595	575 1821	639 2021	697 2205
2½"	210 630	264 792	291 870	331 1048	423 1340	499 1579	564 1786	677 2141	773 2445	858 2714	936 2961
2¾"	281 843	354 1060	389 1161	449 1422	574 1817	677 2142	766 2422	918 2904	1048 3317	1164 3683	1270 4017
3"	373 1120	470 1410	515 1545	597 1847	763 2414	899 2845	1017 3217	1220 3857	1392 4405	1547 4892	1587 5335

TABLE No. 57—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 6 INCH ORIFICE METER

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 6" Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
¾"	13 40	17 51	18 56	21 69	27 88	32 104	37 117	44 141	50 161	56 179	61 195
⅞"	18 55	23 65	25 76	29 94	37 120	44 142	50 160	60 192	69 220	77 244	84 267
1"	24 72	30 86	33 100	38 123	49 157	58 186	66 210	79 252	90 288	100 319	110 349
1¼"	38 114	48 144	53 158	61 193	78 248	88 292	104 330	125 398	142 452	158 502	172 548
1½"	55 167	70 210	77 231	88 281	113 333	134 424	151 480	182 575	207 657	230 730	251 796
1¾"	77 231	97 290	106 319	122 388	157 496	185 585	209 662	250 793	286 906	318 1006	346 1095
2"	102 306	129 362	141 423	163 516	208 660	245 777	278 879	333 1054	376 1204	422 1336	460 1458
2¼"	132 397	166 470	183 548	211 668	270 855	318 1008	360 1140	432 1367	493 1561	548 1733	597 1891
2½"	167 503	211 594	232 694	268 848	342 1085	404 1278	457 1446	548 1733	625 1980	695 2197	757 2397
2¾"	209 627	263 742	290 865	335 1060	428 1355	504 1597	570 1806	684 2165	782 2472	867 2744	946 2994

TABLE No. 57—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 6 INCH ORIFICE METER—Continued

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 6″ Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
3″	258 775	325 916	358 1069	412 1304	572 1667	621 1965	702 2222	842 2664	962 3042	1068 3377	1165 3684
3½″	388 1163	487 1464	536 1605	615 1947	787 2490	927 2934	1049 3319	1258 3978	1436 4543	1595 5043	1739 5502
3¾″	472 1414	594 1780	654 1951	755 2387	965 3052	1137 3596	1286 4068	1542 4877	1760 5569	1955 6185	2132 6744
4″	571 1712	720 2158	792 2362	915 2893	1169 3699	1378 4358	1559 4930	1869 5911	2134 6750	2370 7496	2585 8174
4¼″	692 2075	870 2600	956 2860	1105 3497	1413 4471	1665 5268	1884 5959	2259 7144	2579 8158	2865 9060	3124 9879
4½″	833 2500	1050 3140	1154 3450	1333 4216	1704 5390	2008 6350	2271 7184	2723 8612	3110 9835	3453 10922	3766 11910

TABLE No. 58—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 8 INCH ORIFICE METER

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 8" Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
¾"	13 40	17 47	18 55	21 69	27 88	32 104	37 117	44 141	50 161	56 179	61 195
1"	24 72	30 85	33 99	38 123	49 157	58 185	66 210	79 251	90 287	100 319	109 348
1¼"	37 113	47 142	52 156	60 192	77 246	91 290	107 328	124 393	142 449	157 498	172 544
1½"	54 164	69 207	76 227	87 278	112 356	132 418	149 474	179 568	204 649	228 720	248 786
1¾"	75 225	94 284	104 311	120 380	153 486	181 573	204 648	245 777	280 887	311 985	340 1075
2"	101 302	127 358	140 418	158 500	202 640	238 755	269 853	323 1023	369 1169	410 1297	447 1415
2¼"	127 380	159 449	175 525	202 640	258 818	305 964	344 1091	413 1307	472 1493	524 1657	571 1805
2½"	158 475	199 562	219 655	252 799	322 1021	380 1203	430 1361	516 1632	589 1864	654 2069	713 2257
2¾"	194 582	244 688	269 804	310 982	396 1255	467 1368	528 1673	634 2006	724 2290	804 2542	877 2774
3"	235 705	296 834	325 974	375 1188	480 1519	565 1790	640 2025	767 2427	876 2772	973 3077	1061 3357

TABLE No. 58—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 8 INCH ORIFICE METER—Continued

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 8″ Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
3½″	334 1000	420 1258	462 1380	532 1685	681 2155	802 2539	906 2872	1088 3442	1243 3931	1380 4364	1505 4761
4″	461 1382	580 1738	638 1909	732 2318	937 2965	1104 3493	1249 3951	1497 4737	1710 5409	1899 6004	2070 6550
4½″	625 1875	787 2359	865 2589	990 3131	1265 4004	1491 4717	1687 5336	2022 6397	2310 7305	2565 8108	2797 8846
5″	839 2515	1057 3160	1160 3467	1327 4197	1697 5368	1999 6324	2261 7154	2712 8576	3097 9793	3438 10870	3749 11859
5½″	1120 3360	1412 3980	1552 4649	1780 5631	2276 7201	2682 8484	3033 9597	3637 11504	4154 13137	4612 14581	5030 15908
6″	1487 4460	1872 5274	2060 6150	2379 7524	3041 9619	3583 11333	4054 12820	4860 15369	5550 17551	6163 19490	6720 21254

TABLE No. 59—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 10 INCH ORIFICE METER

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 10″ Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
1″	24 71	30 85	33 99	38 123	49 157	58 185	66 210	79 250	90 287	100 319	109 348
1¼″	37 112	47 142	52 155	60 192	77 245	91 289	107 327	124 393	142 448	157 497	171 543
1½″	54 162	68 205	75 224	87 277	112 354	132 418	149 472	179 566	204 647	227 718	247 784
1¾″	74 223	93 280	103 307	119 378	152 483	180 570	204 644	244 772	278 882	309 979	338 1068
2″	99 297	124 374	137 410	156 495	200 633	235 746	266 844	320 1012	365 1156	405 1283	442 1400
2¼″	124 374	157 470	173 515	198 629	254 805	300 948	339 1073	406 1286	465 1469	515 1630	563 1779
2½″	155 464	195 584	214 641	247 782	316 1001	372 1179	421 1334	505 1599	577 1826	642 2027	700 2212
2¾″	188 565	238 713	261 782	301 953	385 1219	454 1436	514 1625	615 1947	704 2224	781 2469	851 2693
3″	227 680	286 856	314 940	362 1147	464 1467	547 1728	617 1955	740 2343	845 2676	940 2970	1024 3241
3½″	315 945	397 1190	436 1305	504 1595	645 2040	760 2403	859 2719	1030 3259	1177 3722	1306 4131	1425 4507

TABLE No. 59—Showing Maximum and Minimum Capacity per Hour of the Various Sizes of Thin Plate Orifices at Different Pressures, using a 50 Inch Differential Chart. Minimum Differential Pressure 5 Inches. Specific Gravity of Gas .6. Pressures Taken 2½ Diameters Up Stream and 8 Diameters Down Stream.

FOR 10 INCH ORIFICE METER—Continued

All Capacities Given in Hundreds of Cubic Feet

Diam. of Orifice for 10″ Casting	Pressure—Pounds Per Square Inch										
	1	10	15	25	50	75	100	150	200	250	300
4″	423 1270	533 1600	587 1755	678 2147	867 2745	1022 3235	1156 3659	1387 4387	1584 5009	1758 5560	1917 6066
4½″	555 1665	700 2099	770 2300	889 2814	1137 3598	1340 4240	1516 4796	1817 5749	2076 6565	2305 7287	2513 7950
5″	717 2153	903 2709	993 2970	1145 3623	1464 4632	1725 5483	1952 6174	2340 7401	2672 8452	2967 9381	3236 10235
5½″	913 2718	1150 3442	1263 3780	1459 4617	1866 5905	2199 6957	2487 7869	2982 9433	3406 10772	3782 11957	4124 13045
6″	1149 3442	1447 4335	1590 4750	1850 5852	2365 7484	2787 8817	3153 9974	3781 11957	4317 13654	4794 15155	5227 16534
6½″	1459 4375	1837 5500	2020 6035	2343 7412	2996 9479	3531 11168	3993 12633	4788 15143	5468 17293	6071 19194	6621 20941
7″	1835 5500	2310 6925	2540 7600	2934 9280	3751 11864	4420 13979	5000 15813	5994 18956	6845 21648	7602 24040	8290 26215
7½″	2295 6870	2887 8650	3175 9480	3668 11600	4690 14831	5525 17474	6250 19767	7493 23696	8557 27061	9529 30051	10362 32770

TABLE No. 60—To Determine the Percentage, Fast or Slow, of Meter Reading, when the Differential Hand is Registering Too High or Too Low.

If Differential Pen Arm is Found to be Registering Too Low, the Correcting Factor is For:			Differential Reading as Shown on Chart.	If Differential Pen Arm is Found to be Registering Too High, the Correcting Factor is For:		
3 in. Too Low.	2 in. Too Low.	1 in. Too Low.		1 in. Too High.	2 in. Too High.	3 in. Too High.
58%—	41%—	22%—	2	29%+	......	......
41 —	29 —	15 —	3	18 +	42%+	......
32 —	22 —	12 —	4	13 +	29 +	50%+
26 —	18 —	9 —	5	11 +	22 +	37 +
22 —	15 —	8 —	6	9 +	18 +	29 +
19 —	13 —	7 —	7	7 +	15 +	24 +
17 —	12 —	6 —	8	6 +	13 +	21 +
15 —	11 —	5 —	9	6 +	12 +	18 +
14 —	9 —	5 —	10	5 +	11 +	16 +
13 —	8 —	4 —	11	5 +	10 +	15 +
12 —	8 —	4 —	12	4 +	9 +	13 +
11 —	7 —	4 —	13	4 +	8 +	12 +
10 —	7 —	3 —	14	4 +	7 +	11 +
10 —	6 —	3 —	15	3 +	7 +	11 +
9 —	6 —	3 —	16	3 +	6 +	10 +
8 —	6 —	3 —	17	3 +	6 +	9 +
8 —	5 —	3 —	18	3 +	6 +	9 +
8 —	5 —	3 —	19	3 +	5 +	8 +
7 —	5 —	2 —	20	3 +	5 +	8 +
7 —	5 —		21	2 +	5 +	7 +
7 —	4 —	Less than 2 per cent.	22	Less than 2 per cent.	5 +	7 +
6 —	4 —		23		4 +	7 +
6 —	4 —		24		4 +	6 +
6 —	4 —		25		4 +	6 +
6 —	4 —		26		4 +	6 +

TABLE No. 60 (Continued)—**To Determine the Percentage, Fast or Slow, of Meter Reading, when the Differential Hand is Registering Too High or Too Low.**

If Differential Pen Arm is Found to be Registering Too Low, the Correcting Factor is For:			Differential Reading as Shown on Chart.	If Differential Pen Arm is Found to be Registering Too High, the Correcting Factor is For:		
3 in. Too Low.	2 in. Too Low.	1 in. Too Low.		1 in. Too High.	2 in. Too High.	3 in. Too High.
5%—	4%—	Less than 2 per cent.	27	Less than 2 per cent.	4%+	6%+
5 —	4 —		28		4 +	6 +
5 —	3 —		29		4 +	5 +
5 —	3 —		30		3 +	5 +
5 —	3 —		31		3 +	5 +
5 —	3 —		32		3 +	5 +
4 —	3 —		33		3 +	5 +
4 —	3 —		34		3 +	5 +
4 —	3 —		35		3 +	4 +
4 —	3 —		36		3 +	4 +
4 —	3 —		37		3 +	4 +
4 —	3 —		38		3 +	4 +
4 —	3 —		39		3 +	4 +
4 —	2 —		40		3 +	4 +
4 —	Less than 2 per cent.		41		2 +	4 +
4 —			42		Less than 2 per cent.	4 +
3 —			43			4 +
3 —			44			3 +
3 —			45			3 +
3 —			46			3 +
3 —			47			3 +
3 —			48			3 +
3 —			49			3 +
3 —			50			3 +

INSTALLING ORIFICE METERS AND DIFFERENTIAL GAUGES

This company publishes a series of instruction circulars as listed in the back of this book. Among them is a circular giving instructions for installing orifice meters and gauges. This circular will be sent on request.

In this chapter no article on the installation of orifice meter and gauges will appear.

In addition to this circular, the hand book, "Measurement of Gas by Orifice Meter," fully covers the subject of installing orifice meters and differential gauges.

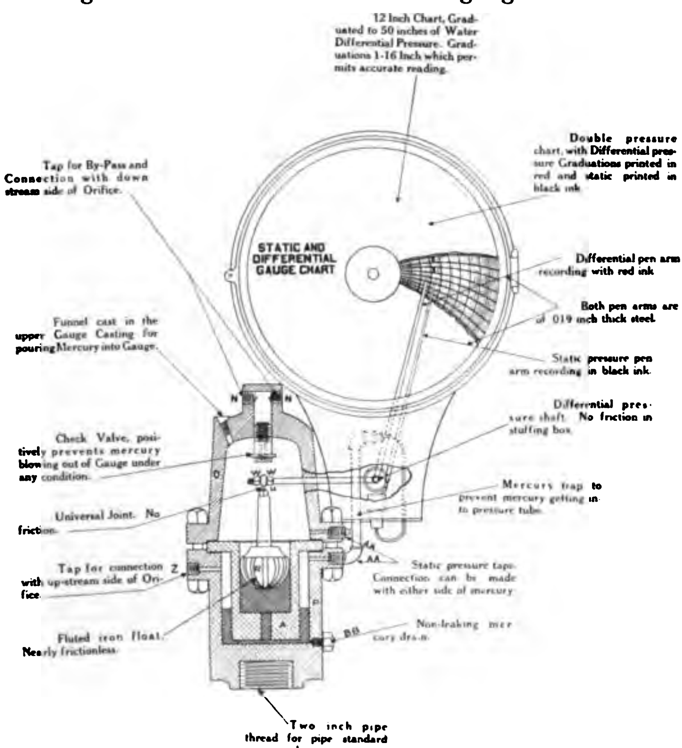


Fig. 135—ONE TYPE OF 50 INCH DIFFERENTIAL GAUGE

Fig. 186—AN EIGHT-INCH ORIFICE METER INSTALLATION

DIFFERENTIAL REGULATOR

Where gas is measured by orifice meter for city consumption the range of flow varies greatly throughout the day. The difference in the load between midnight and morning is invariably too great to be measured by one sized orifice. It is also impracticable for the gas company to keep a man at the installation constantly, either changing orifices or changing the flow of gas from one meter to another.

The differential regulator with a double orifice meter installation has been found to be very successful. It is placed back of one orifice meter and the chambers on either side of the diaphragm are connected with the pipe line on either side of the orifice on the other meter. In other words, the regulator diaphragm is actuated by the differential pressure of the other orifice meter. When the differential pressure on the meter constantly in use exceeds 50 inches or any other predetermined differential pressure, the regulator valve opens and puts the second meter in use. When the differential pressure drops to below 10 or 15 inches or some predetermined point, the differential regulator shuts off the gas to the second meter and the entire load is thrown on to the first meter. This greatly increases the capacity by using two meters, yet when the load reaches its minimum the gas is measured by one orifice meter and with more accurate results.

TO READ CHARTS

Explanation of the Pressure Extensions—Usually the coefficient for various sized orifices is given for hourly readings. When this is the case, average the static and differential pressures hourly on the chart. Substitute the differential pressure figures in place of *h* and the static pressure in place of *p* in the following formula:

$$\text{Co.}\ \sqrt{h\ (14.4+p)} = \text{cu. ft. of gas per hour.}$$

where Co. = hourly coefficient.

Differential and static pressure readings should be averaged each hour throughout the 24 hours and the pressure extension for each hour multiplied by the hourly coefficient or the hourly pressure extensions added for 24 hours and the result multiplied by the coefficient.

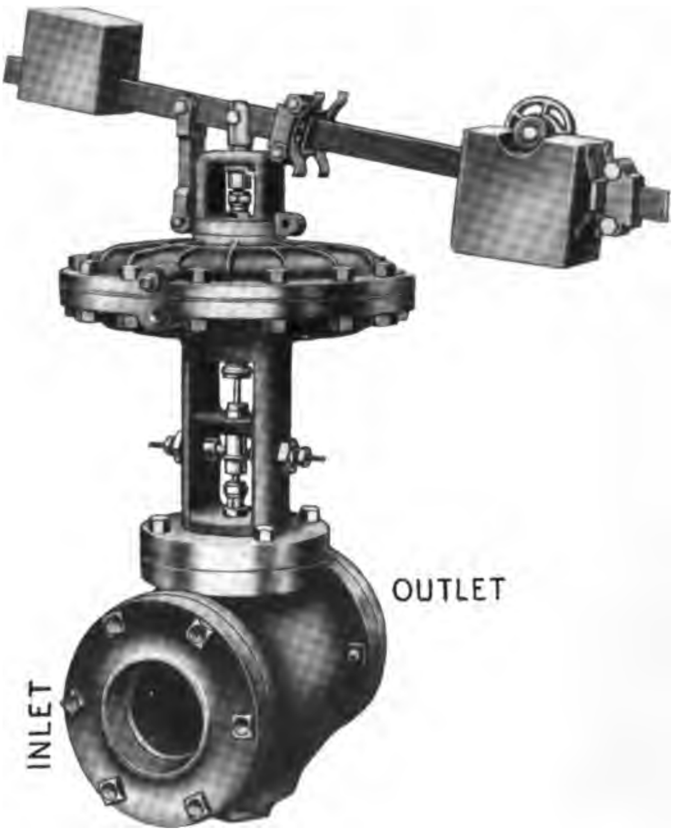


Fig. 137—DIFFERENTIAL REGULATOR

AVERAGING PRESSURES ON CHARTS

The most accurate method to employ is to average the pressure for each hour or each fifteen-minute period. The former is most commonly used. There are a few companies that use a three-hour period but the use of this length of time in averaging charts should be discouraged.

The planimeter can be used, but is not quite as accurate as the personal observation method in hourly periods. In averaging a series of charts by both the planimeter and personal observation the difference was found to range less than two per cent.

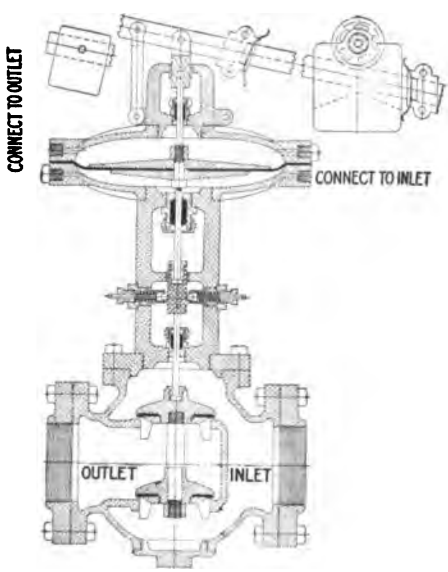


Fig. 138—SECTIONAL VIEW OF DIFFERENTIAL REGULATOR

LARGE CAPACITY METER

Large Capacity Meter—Where the volume of gas or air to be measured exceeds 3,000 cubic feet per hour, or the pressure is above five pounds, the most practical and cheapest method of measurement is by a proportional or large capacity meter. Many gas companies use a large capacity meter to measure a volume of gas as small as 2,000 cubic feet per hour at a low pressure.

While it is true that in the early days of large volume, high pressure gas measurement, the proportional meter bore a doubtful reputation, during recent years many improvements have been made in these instruments, and they have been brought to a high standard of efficiency and accuracy.

The large capacity meter is a most important instrument to the natural gas fraternity and without doubt there is less known about it by the actual caretaker than about any other piece of apparatus under his care. It is seldom taken into consideration that it is a hard-worked piece of machinery, receiving little care and attention. Many instances are known where large capacity meters were not even cleaned, although in constant use for a period of two years or longer. While as a rule it is not good policy to repair a meter in the field without subsequent testing, nevertheless there are a great many things that may happen to it which would only call for the tightening of a nut or screw, or replacing some part that would not affect the accuracy of the meter whatever.

The large capacity meter, like any other sensitive instrument, needs attention. It is often blamed for a great deal of inaccuracy that should be charged to the pipe line. If a meter is believed to be inaccurate, it should be very carefully tested by a competent meter man, and if any controversy exists it would be policy to have the meter tested once a month and all records of tests kept on file at the gas company's office. When a gas company, selling to

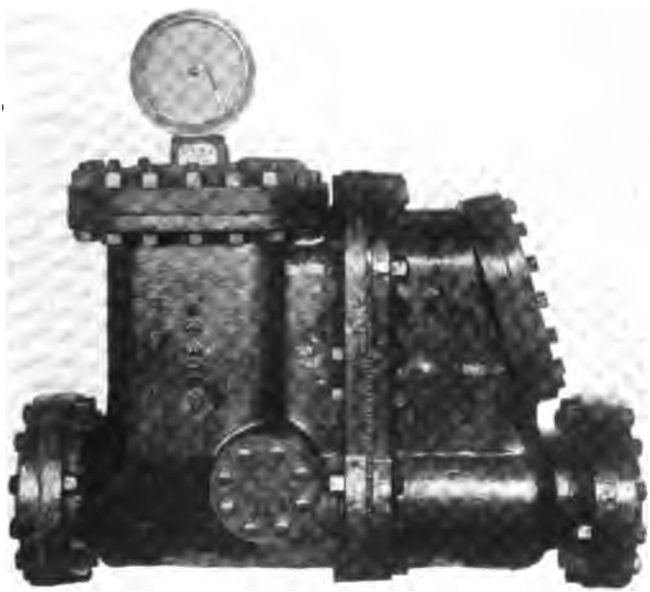


Fig. 139—500-LB. TEST LARGE CAPACITY METER
With Volume and Pressure Recording Gauge.

another company in the field, decides to have a test made, it is no more than fair (whether a disagreement exists or not) that the other interested party should be asked to have a representative present during the test. The results of the test should not be kept secret but should be held as common property between the two companies interested. Secrecy in testing meters often breeds trouble and creates a great deal of unnecessary dissatisfaction.

Measure gas at as low a pressure as possible. It is customary to measure gas on a four ounce basis unless otherwise specified in a preliminary agreement. A great many field companies purchase gas on an eight ounce basis. The slight

advantage gained by this increased pressure is supposed to offset the small loss caused by the pipe line leakage.

A factory meter measuring gas at a low pressure will only measure accurately a volume of low-pressure gas up to its rated capacity in cubic feet, while a field or high-pressure meter will measure accurately a volume of low-pressure gas at a high pressure far in excess of the rated capacity of the meter, entirely dependent upon the pressure. For example, a 10,000 cubic foot per hour, large capacity dry meter will measure accurately as follows:

TABLE No. 61

Meter Reading	Pressure Pounds per Square Inch	Multiplier or Density	Actual Amount of Low Pressure Gas Measured
10,000	.25	1.0000	10,000
10,000	100.00	7.8088	78,088
10,000	200.00	14.6348	146,348

The above figures are given under the assumption that the meter is working up to its maximum capacity, or 10,000 cubic feet per hour meter reading.

To determine the proper-sized meter to measure any volume the following rule is followed:

Divide the volume of gas to be measured per hour by the multiplier or density at which the gas is to be measured and it will give the meter reading for which to select the proper sized meter.

Example:—If it is desired to measure 146,348 cubic feet of low pressure gas per hour at a pressure of 200 pounds — 146,348 ÷ 14.6348 = 10,000 cubic feet per hour meter reading.

Range of Accuracy of Large Capacity Meter—A large capacity meter is tested and corrected to within two per cent of accuracy within the limits of its capacity.

Accurate measurement cannot be expected below a certain minimum volume which will vary according to the rated capacity of the meter. From the writer's experience, a table is given below showing a reasonable minimum range of accuracy for meters of different types and rated capacities.

TABLE No. 62

Capacity of Meter Cu. ft. per hour. (Meter Reading)	Minimum Range of Accuracy Cu. ft. per hour (Meter Reading)
3,000	500
6,000	700
10,000	900
20,000	1,800
35,000	3,600
50,000	3,600
75,000	3,600
100,000	3,600
125,000	7,200
150,000	10,800

All sizes of the different makes are tested in the factory to smaller volumes than those given above but it is extremely difficult to retain this accuracy on such small volumes in an instrument that was designed for heavier duty both as to pressure and volume.

For volumes under 1,000 cubic feet per hour it is best to use a positive meter.

To expect any type or make of meter to measure a wide range of volumes—for example a 20,000 cubic feet per hour capacity meter to measure a minimum volume of 600 cubic feet per hour is unreasonable. It might be likened to a merchant weighing a pound of butter with a set of hay scales.

Where, in the same pipe line it is necessary to measure large and small volumes of extremely wide range, it is more reasonable to use two different size meters; a large size for

the large volume and a smaller size for the small volume. By so doing very close accuracy can be obtained.

A large capacity meter given proper care and used within its rated capacity will prove to be a wonderfully accurate measuring instrument.

Factory Proving of Large Capacity Meters—Large capacity meters are proved in the factory for volume with air at four inches water pressure corrected to the barometer and thermometer readings at time of test. The proving instruments used are the standard flow meter, funnel meter and a large prover. In field proving, an additional correction is made on the pressure for the difference between the specific gravity of the gas and the air (air being 1).

Pressure Testing of Large Capacity Meters—Hydraulic water pressure is used in testing large capacity meters for leaks, imperfections in castings and strength of metal. Following water test, air under high pressure is used.

Fifty pound meters are tested up to seventy-five pounds. Two hundred pound meters are tested up to two hundred and fifty pounds. Five hundred pound meters are tested up to five hundred and fifty pounds.

Advantage should not be taken of the pressure test above the rated strength of the meter, as this additional test is made as a precautionary measure.

Over Capacity in Large Capacity Meters—All dry meters will work over capacity to a reasonable extent, especially the small sizes. For instance the 6,000 cubic feet per hour meter will measure accurately up to 7,200 cubic feet per hour. It is not good policy to take advantage of this over capacity constantly, but if used occasionally it will not injure the meter.

Invariably the differential above the rated capacity of the meter increases greatly out of proportion to the differential of the meter within capacity.

TABLE No. 63

To Determine the Proper Size Meter, in Measuring Low and High Pressure Gas with the Large Capacity Dry Meter, where the Maximum Volume per 24 Hours is Given at Four Ounces Pressure Above an Atmospheric Pressure of 14.4 lb. per Square Inch.

Max. Volume per Hour Cu. Ft.	Max. Volume per 24 Hours Cu. Ft.	Capacity of Meters at Different Pressures in Cu. Ft. per Hour								
		4 Oz.	25 Lb.	50 Lb.	75 Lb.	100 Lb.	150 Lb.	200 Lb.	300 Lb.	400 Lb.
6,000	150,000	6,000	3,000	3,000	3,000	*	*	*	*	*
10,000	250,000	10,000	6,000	3,000	3,000	3,000	*	*	*	*
20,000	500,000	20,000	10,000	6,000	6,000	3,000	3,000	3,000	*	*
41,000	1,000,000	50,000	20,000	10,000	10,000	6,000	6,000	3,000	3,000	3,000
62,000	1,500,000	75,000	20,000	20,000	10,000	10,000	10,000	6,000	3,000	3,000
83,000	2,000,000	100,000	35,000	20,000	20,000	10,000	10,000	10,000	6,000	3,000
104,000	2,500,000	100,000	35,000	20,000	20,000	20,000	10,000	10,000	6,000	6,000
125,000	3,000,000	125,000	50,000	35,000	20,000	20,000	20,000	10,000	10,000	6,000
146,000	3,500,000	150,000	50,000	35,000	35,000	20,000	20,000	20,000	10,000	6,000
166,000	4,000,000	†175,000	75,000	35,000	35,000	35,000	20,000	20,000	10,000	10,000
208,000	5,000,000	†200,000	75,000	50,000	35,000	35,000	20,000	20,000	10,000	10,000
250,000	6,000,000	†250,000	100,000	75,000	50,000	35,000	35,000	20,000	20,000	10,000
330,000	8,000,000	†325,000	125,000	75,000	75,000	50,000	35,000	35,000	20,000	20,000
416,000	10,000,000	†400,000	150,000	100,000	75,000	75,000	50,000	35,000	20,000	20,000
500,000	12,000,000	†500,000	†200,000	125,000	100,000	75,000	50,000	50,000	35,000	20,000
625,000	15,000,000	†600,000	†225,000	150,000	125,000	100,000	75,000	50,000	35,000	35,000
832,000	20,000,000	†825,000	†300,000	†200,000	150,000	125,000	75,000	75,000	50,000	35,000

* Use high pressure tally meters for these capacities. † Use two or more meters in battery form.

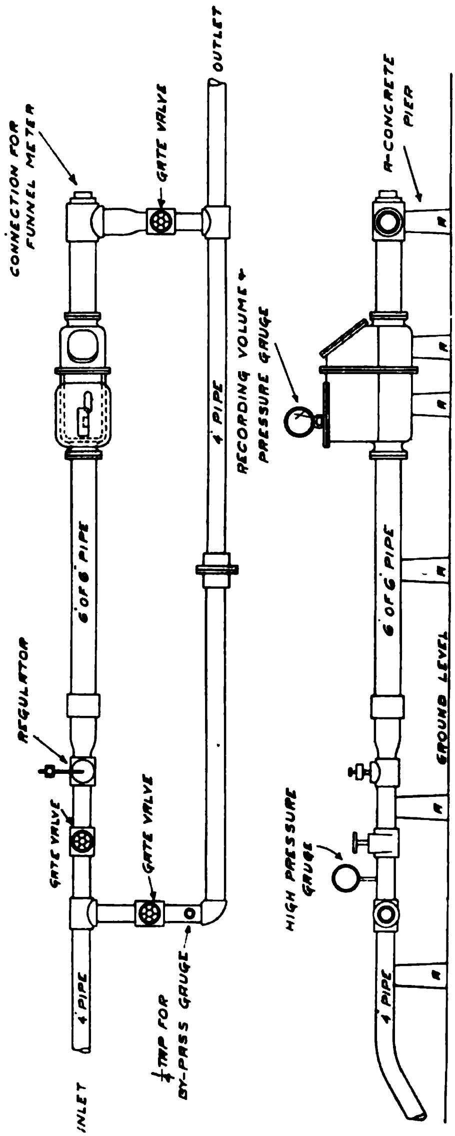


Fig. 140—SETTING FOR SIX-INCH LARGE CAPACITY METER

Installation—It is essential to use the proper amount of pipe on the inlet of the meter as designated in the directions for installing. For instance, in the case of an 8-inch meter, at least eight feet or more of 8-inch pipe should be used into the inlet flange. The meters are tested under these conditions in the factory and if the directions are not followed (as by using 4-inch pipe directly into an 8-inch meter, or by placing an ell, gate, or regulator within less than eight feet from the inlet flange of an 8-inch meter) the tendency would be to create counter currents or eddies and cause the meter to run slow.

All large capacity meters should be set absolutely level on a solid foundation, concrete being the most desirable. In measuring gas in the field under high pressure in cold weather, the very best results are obtained by using a system of heating without bringing the fire in too close proximity to the meter location in the interior of the building. This can be done by using 6- or 8-inch pipe or casing, building your torch fire ten or twelve feet away from the building, and constructing your flue and chimney from the fire directly through the building to the further end, then through the roof. That portion of pipe between the fire and the building, with the exception of directly at the location of fire, can be banked over with dirt, thereby preventing radiation of the heat until after the pipe enters the building. This method merely conducts the burnt gases and heat through the 6- or 8-inch pipe or casing into the building and through the roof, having the same effect as steam, but without any danger of explosion.

Cleaning—The question is often asked, "How often shall we clean our meter?" This is a hard question to answer for the reason that there are no two conditions found to be alike in the gas that passes through the meter. It is better to clean the meter too often than not often enough. One

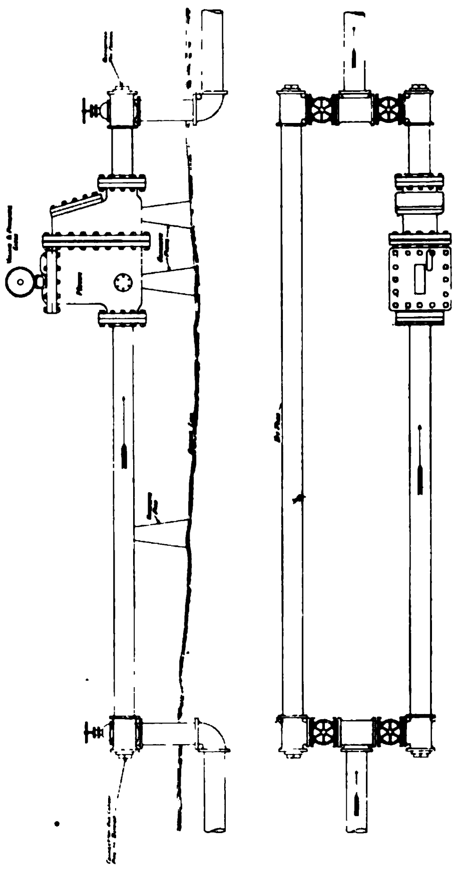


Fig. 141—CASINGHEAD GAS METER INSTALLATION. TEES ON INLET SIDE OF METER ARE FOR CONNECTION WITH BLOWER WHEN TESTING WITH AIR

TABLE No. 64

Proper Sized Meter to Install Where Gas is Used to Generate Power Either in a Gas Engine or Under Steam Boilers.

Horse-power of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour		Horsepower of Engine or Boilers	Capacity of Meter In Cu. Ft. per Hour	
	In Gas Engine	Under Steam Boiler		In Gas Engine	Under Steam Boiler
10	500	800	150	3,000	10,000
15	500	1,500	200	6,000	20,000
20	800	1,500	300	6,000	20,000
25	800	3,000	400	10,000	35,000
35	1,500	3,000	500	10,000	35,000
50	1,500	6,000	600	10,000	50,000
75	3,000	6,000	800	20,000	50,000
100	3,000	10,000	1000	20,000	75,000

can judge by the condition the meter is found to be in at each cleaning.

By-Pass—It is considered objectionable by the majority of gas people to use a by-pass around the meter on account of the liability of leakages in the gate, causing loss of measurement. Where meters are in use twenty-four hours a day (such as at glass factories and cement plants), and there is no possibility of shutting the gas off to make a test or repairs, a by-pass is very essential unless a duplicate meter is used. The practice of installing two meters, one in case of emergency, is seldom followed on account of the additional cost.

In the case above mentioned the by-pass method can be employed without any loss whatever by the use of double gates and two pieces of pipe between the gates, with an expansion sleeve that can readily be detached after the test or repair is made. This leaves the by-pass broken and the gates can be plugged except when the by-pass is actually in use.

Table No. 65—Table to Determine the Proper Sized Meter, to be Used in Measuring Air, from Atmospheric Pressure up to 120 Pounds to the Square Inch, with a Large Capacity Meter, where the Maximum Volume per Minute of Free Air is Given.

Maximum Volume Free Air per Minute Cubic Feet	Capacity of Meters at Different Pressures In Cubic Feet per Hour				
	Atmospheric Pressure	30-Lb.	60-Lb.	90-Lb.	120-Lb.
50	3,000	3,000	*	*	*
100	6,000	3,000	3,000	*	*
200	10,000	6,000	3,000	3,000	*
300	20,000	6,000	6,000	3,000	3,000
400	35,000	10,000	6,000	6,000	3,000
500	35,000	10,000	6,000	6,000	6,000
600	35,000	20,000	10,000	6,000	6,000
800	50,000	20,000	10,000	10,000	6,000
1,000	75,000	20,000	20,000	10,000	10,000
2,000	125,000	50,000	35,000	20,000	20,000
2,500	†275,000	50,000	35,000	35,000	20,000

*Use tally meters encased to stand high pressure.
†For this volume use battery of meters.

Turning Gas Into a Meter—While this may seem a simple subject, it is one of the most important instructions that can be given in the care of large capacity meters, especially in measuring high pressure gas.

Gas should be turned into the inlet first, and **very slowly.** When the pressure in the meter equals the pressure in the line ahead of the meter open the outlet gate **very slowly.**

Turn gas into a field meter with the same precaution you would use in starting an automobile. By that is meant—start on low gear, advance to second then after car is under way throw the gears into high speed. It is just as harmful to turn high pressure gas into a meter suddenly as it is to start an automobile on high gear or speed.

Condensation—All natural gas direct from the well carries more or less aqueous vapor.

Condensation in pipe lines, regulators and large capacity meters is caused by the difference in temperature of the gas and air. If the gas is warmer than the air the condensation will be on the interior of the pipe, regulator, or meter; and if the gas is colder than the air, the condensation will be on the exterior. This condensation is commonly called sweating, being the moisture condensed from the atmosphere surrounding the pipe.

A gas torch placed on a gas line directly back of a drip will cause condensation of aqueous vapor in the drip where the condensed vapor is taken care of and will protect the meter or regulator if located ahead of and near the drip.

Drain Cocks—All meters should be installed with drain cocks on the inlet and outlet bowls to keep the meter absolutely dry. The fact that the gas in the well is dry is no guide to go by, for the gas may carry aqueous vapor and might find conditions en route from well to the meter that would cause it to condense into free water.

Lighting Measuring Stations—Where possible in installing a meter or regulator station, equip the house with one or two electric light bulbs with long wiring. Use a wire cage over the bulb. Place a switch on the outside of building or on some adjacent post or tree. Lightning arresters should be used.

Large Capacity Meter Gaskets—For 50 lb. and 200 lb. meters use soft cardboard gaskets about $\frac{1}{16}$-inch thick. Apply white lead on both sides of the gasket.

For 500 lb. meter gaskets use asbestos board $\frac{3}{32}$-inch thick. Dampen before using. Apply coating of asphaltum on both sides of the gasket after dampening.

To Read a Large Capacity Meter—In reading a meter the small or 100 foot dial should not be considered. Each sub-

division in the circle represents one-tenth of the figures placed above the circle. In other words, on the 10,000-foot dial, if the hand points between 7 and 8, the figure the hand has just passed (which would be 7) indicates that over 7,000 cubic feet have passed. The 1000-foot dial is only taken into consideration when the hand points between 5 and 0, in which case it is counted as 1,000. In the foregoing case, if the hand on the 10,000-foot dial was close to 8 and the hand in the 1000-foot pointed at 8 or 9, the reading of the 10,000-foot dial would be 8,000. Each dial above the 10,000-foot dial is read the same as the one described above.

In reading the dial no attention should be paid to the wording "one per cent." or "two per cent." printed on the face of the dial. The wording is intended for use when ordering a new clock or tally, and has no bearing on the meter reading.

Field Testing—During the past few years testing in the field with the funnel meter has become very common. No doubt there are objections to this method, but on the other hand there are advantages that cannot be obtained by shipping the meter to the factory. For instance, the natural jarring and knocking about that a meter receives en route from the lease location to the factory, may cause a great deal of the dirt collected on the valves to be jarred off, preventing the owner from obtaining a true test of what it

Fig. 142—COMPLETE FIELD TESTING OUTFIT WITH BOX FOR SHIPPING

Fig. 143—FIELD TESTING OUTFIT FOR LARGE CAPACITY GAS METERS. THIS METHOD IS QUITE NECESSARY WHERE METERS ARE MEASURING UNDER A VACUUM, AND IS A GREAT SAVER OF GAS WHEN THERE IS PLENTY OF IT AT A PRESSURE. *Air is Used Instead of Gas. Sufficient Volume and Pressure is Supplied by a Small Blower*

was doing while in actual service in the field. It is also true that a large capacity meter in the field can be tested with the funnel meter and repaired under average circumstances in a period of a few hours, or not to exceed two or three days. The old method generally kept the meter out of service for a period of from two to six weeks while being tested and repaired at the factory.

The error generally allowed in the field is 3 per cent. fast or slow, while the factory is confined to a 2 per cent. error either fast or slow.

Funnel Meter—While it is true that the funnel meter is a simple instrument, yet in order to obtain reliable results with it, it is very essential that the operator should be experienced in the use of the instrument and at the same time have a thorough knowledge of how to repair and correct the meter being tested. The proper place to gain this experience is at the factory. The most successful combination to make a large capacity meter expert is the actual experience in the field with experience of large capacity meter testing derived in the factory.

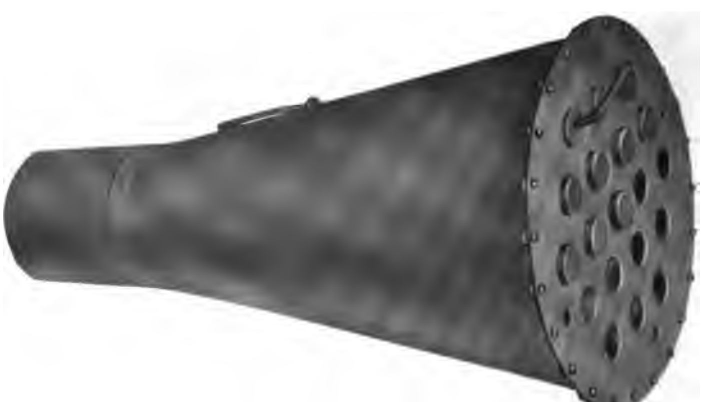


Fig. 144—FUNNEL METER WITH DETACHABLE HEAD
For Testing Large Capacity Meters in the Field.

Great care should be used not only in handling but in storing the funnel meter when not in use. The edge of the different orifices should be kept perfectly dry. Rusting of the edges of the orifices will create inaccuracy in testing, and should this occur the funnel meter should be repaired and re-tested at the factory. In case the head—carrying the orifices—becomes dented, it is also necessary to have the funnel meter re-tested.

Fig. 145—TESTING A CASINGHEAD GAS METER IN THE FIELD WHERE GAS IS UNDER A VACUUM.

PROVING CASINGHEAD GAS METERS

Invariably casinghead gas is measured by a meter under a vacuum pressure. In order to test the meter residue, gas or air under pressure must be used. As residue gas lines are not always near the meter location, the practical

method to pursue is to use a proving outfit installed on a Ford car, as shown in Fig. 143. Power is furnished by jacking one rear wheel off the ground and connecting the pulley on the blower to the wheel by a belt. The outlet of the blower is connected to the inlet of the meter by a canvas pipe. In determining the proper pressure to carry on the funnel it is not necessary to correct it for specific gravity.

For the past three or four years several large gasoline companies in Oklahoma have been making it a practice to remove the tallies from their Westcott Meters, repairing and testing them in a meter-proving room at the plant and after reinstalling them would invariably find the meter to be within two per cent. of accuracy. They carried a few extra tallies which were kept in perfect condition, and as soon as an old tally was removed from the meter one of the tallies from stock was substituted. By following this method the meter was not out of service but for a very short period of approximately one hour. No filing or soldering on the proportional valve was found necessary, the meter was very carefully cleaned, and all bearing points properly oiled and the parts in the main body of the meter were not otherwise changed. The writer has carefully watched the results of the above method for the past two or three years and does not hesitate to suggest that other companies follow the same method.

One great advantage is that the only work done in the field is the cleaning and oiling of the meter, the delicate work of proving and repairing the tally, if it needs it, is done in the meter shop where one is protected from the weather. This method calls for the installation of a five-foot prover in the meter shop, but the time saved over the old method would soon offset the cost of the new equipment.

If meters are placed in the pipe line in which there is pulsation or vibration in the gas, the above statement should not apply, as there would have to be some soldering done on the under part of the proportional valve to offset the wear due to the pulsation.

The portable proving outfit shown in Fig. 143 is fast becoming standard with the natural gas men. Even though the producer may have plenty of gas at a high pressure, the use of the portable air proving outfit for proving large capacity meters in the field is one step toward the true conservation of gas.

Funnel Meter Testing Pressure—To determine the correct pressure of the gas flowing through the funnel meter orifices while testing meters it is necessary to take into consideration the temperature of the flowing gas, the barometer reading and the specific gravity of the gas used. The formula is as follows:

$$\frac{B}{.0138\,(T+460)} \times S = P.$$

In which

B = Barometer reading in inches of mercury
T = Temperature of flowing gas in deg. fahr.
S = Specific gravity of gas used.
P = Pressure to be carried on gas flowing through funnel meter orifices.

In the above formula 460 is the absolute temperature below zero, and .0138 is the constant determined by actual tests. The table found on pages 410 and 411 is worked out by the following formula:

$$\frac{B}{.0138\,(T+460)} = P.$$

in which P equals the pressure to be used when testing with air. In using the table on pages 410 and 411 in testing with gas it is necessary to multiply the correct pressure in the table by the specific gravity of the gas.

In proving it is necessary to use a common six inch or larger siphon gauge and a few feet of common three-eighth inch rubber tubing to connect the gauge with the one-

eighth inch nipple found in one of the rubber plugs accompanying the funnel. This rubber plug should be inserted in one of the orifices on the face of the funnel. Fill the siphon gauge until the water level reaches the zero mark. When the rubber plug with the small nipple is connected with the siphon gauge, it will show the gas pressure on the face of the funnel meter.

After the funnel has been properly attached to the meter, either into a tee in the pipe line between the outlet flange and the gate ahead of the meter, or by screwing it directly into the end flange bolted to the outlet of the meter, the gas should be turned on very slowly, especially if the pressure behind the inlet gate is high, and the meter allowed to run for a few minutes prior to starting the actual test. During this period, an inspection of the joints or connections should be made, between the funnel and the inlet of the meter. Even though the pressure carried through the meter is very low, small leaks ahead of the meter will have considerable bearing upon a true test. Soap suds and a large brush can be used to advantage. Leaks on the inlet to the meter will have no effect on the test.

The meter should be proved from a small volume up to and just above the maximum capacity of the meter. For instance, if it is a 20,000 foot meter, test should begin at 3,600 feet per hour, or with one 1½-inch hole open and up to 21,600 feet per hour, or six 1½-inch holes open. In proving this size meter, tests should be made with two, three, four, five, and six holes open.

Use water in the siphon gauge, filling it to the zero mark in center of the scale.

After the funnel has been set or installed, and the gas turned on, the temperature of the flowing gas through the funnel should be taken, and the barometer reading observed, to assist in determining the proper pressure to carry.

To determine the proper pressure to carry on the funnel, after noting the barometer, thermometer readings and specific gravity of the gas, see table on pages 410 and 411, and select the pressure corresponding to your thermometer reading in the proper barometer column. The pressure shown in the table is the proper pressure to carry when proving with a funnel using air. In proving with any gas, multiply the pressure found in the table by the specific gravity of the gas.

In reading the siphon gauge, read both sides of the scale, which added together will give the pressure being carried.

If the pressure figures out 2.4 inches, this pressure should be carried throughout the entire test, regardless of the number of holes open in the face of the funnel. Great care should be used to note that the pressure remains constant during each individual test, otherwise a true test of the meter cannot be obtained.

Time of Tests—There being 3600 seconds in an hour, and each 1½ in. hole passing 3600 cubic feet per hour, in running a 100 foot test, each second over or under 100 seconds will mean 1 per cent. For instance, if with one hole open, the meter records 100 feet on the dial in 98 seconds by the stop watch, the meter is 2 per cent fast. If the meter records 100 feet in 102 seconds, the meter is 2 per cent slow. The exception to the above percentage rule is where a meter is running fast and the time is 90 seconds or less. Employ regular percentage rule to determine the per cent fast when the percentage figures are to be used to make a correction in the meter bill for any previous length of time. As far as the mechanical work in correcting the meter is concerned, one second for one per cent can be used, even though the meter records 100 feet in 50 seconds when tested.

Each 1½ in. orifice will pass 3,600 feet per hour, or 100 feet per second. If two holes are open, they will pass twice

TABLE

PRESSURES TO BE USED IN MEASURING AIR

BAROMETRIC PRESSURES

Standard barometer..........29.2 inches Standard temperature...

deg. fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
30	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39	4.40	4.42	4.44
31	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41	4.43
32	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37	4.39	4.40	4.42
33	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37	4.38	4.39	4.41
34	4.20	4.21	4.22	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36	4.37	4.39	4.40
35	4.19	4.20	4.22	4.23	4.25	4.26	4.27	4.29	4.30	4.32	4.33	4.35	4.36	4.38	4.39
36	4.18	4.19	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.32	4.34	4.35	4.37	4.38
37	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33	4.34	4.36	4.37
38	4.16	4.17	4.19	4.21	4.22	4.23	4.25	4.26	4.28	4.29	4.31	4.32	4.34	4.35	4.37
39	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30	4.31	4.33	4.34	4.36
40	4.14	4.15	4.17	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30	4.32	4.33	4.35
41	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28	4.29	4.31	4.32	4.34
42	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29	4.30	4.32	4.33
43	4.12	4.12	4.15	4.16	4.18	4.19	4.21	4.22	4.24	4.25	4.26	4.28	4.29	4.31	4.32
44	4.11	4.13	4.14	4.16	4.17	4.18	4.20	4.21	4.23	4.24	4.26	4.27	4.28	4.30	4.31
45	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26	4.28	4.29	4.30
46	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25	4.27	4.28	4.30
47	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.22	4.23	4.24	4.26	4.27	4.29
48	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22	4.24	4.25	4.27	4.28
49	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.23	4.24	4.26	4.27
50	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25	4.26
51	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20	4.21	4.23	4.24	4.25
52	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.18	4.19	4.20	4.22	4.23	4.25
53	4.04	4.05	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.17	4.18	4.20	4.21	4.22	4.24
54	4.03	4.05	4.06	4.07	4.09	4.10	4.12	4.13	4.14	4.16	4.17	4.19	4.20	4.21	4.22
55	4.02	4.04	4.05	4.07	4.08	4.09	4.11	4.12	4.14	4.15	4.17	4.18	4.19	4.21	4.22
56	4.02	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.16	4.17	4.19	4.20	4.21
57	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.13	4.15	4.16	4.18	4.19	4.20
58	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.13	4.14	4.15	4.17	4.18	4.20
59	4.00	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15	4.16	4.17	4.19
60	3.99	4.01	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.12	4.13	4.14	4.16	4.17	4.18
61	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.08	4.10	4.11	4.12	4.14	4.15	4.16	4.17
62	3.97	3.99	4.00	4.02	4.03	4.04	4.06	4.07	4.08	4.10	4.11	4.13	4.14	4.15	4.16
63	3.97	3.98	3.99	4.00	4.02	4.04	4.05	4.06	4.08	4.09	4.11	4.12	4.14	4.15	4.16
64	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.06	4.07	4.09	4.10	4.11	4.12	4.14	4.15
65	3.95	3.96	3.98	3.99	4.01	4.02	4.04	4.05	4.06	4.08	4.09	4.10	4.12	4.13	4.15
66	3.94	3.96	3.97	3.99	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.10	4.11	4.13
67	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.07	4.08	4.09	4.10	4.11	4.12
68	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.03	4.04	4.05	4.07	4.08	4.09	4.11	4.12
69	3.92	3.93	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.06	4.07	4.09	4.10	4.11

No. 66

THROUGH A FUNNEL METER AT DIFFERENT AND TEMPERATURES

.......70 deg. fahr. Standard pressure........4 inches water

deg. fahr.	Barometer Reading														
	28.6	28.7	28.8	28.9	29.0	29.1	29.2	29.3	29.4	29.5	29.6	29.7	29.8	29.9	30.0
	Pressure in Inches of Water														
70	3.91	3.92	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04	4.06	4.07	4.07	4.08	4.10
71	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.02	4.03	4.05	4.05	4.05	4.07	4.09
72	3.91	3.91	3.93	3.94	3.96	3.97	3.99	4.00	4.01	4.01	4.02	4.03	4.05	4.06	4.08
73	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	4.03	4.05	4.06	4.08
74	3.90	3.90	3.91	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.03	4.06	4.06	4.07
75	3.88	3.90	3.90	3.92	3.93	3.95	3.96	3.97	3.98	4.00	4.02	4.03	4.03	4.04	4.06
76	3.87	3.88	3.89	3.90	3.93	3.94	3.95	3.96	3.97	4.00	4.01	4.01	4.02	4.04	4.06
77	3.86	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99	4.01	4.01	4.03	4.04	4.06
78	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97	3.98	3.99	4.01	4.02	4.03	4.05
79	3.85	3.86	3.88	3.89	3.90	3.92	3.93	3.94	3.96	3.97	3.98	4.00	4.01	4.02	4.04
80	3.84	3.85	3.87	3.89	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.03
81	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.93	3.94	3.96	3.98	3.99	4.00	4.01	4.02
82	3.83	3.84	3.85	3.87	3.88	3.90	3.92	3.93	3.93	3.96	3.98	3.99	4.00	4.00	4.01
83	3.82	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.92	3.94	3.96	3.97	3.98	3.99	4.00
84	3.82	3.83	3.85	3.86	3.86	3.89	3.90	3.91	3.92	3.94	3.96	3.97	3.97	3.99	4.00
85	3.81	3.82	3.84	3.85	3.86	3.88	3.88	3.90	3.91	3.92	3.94	3.95	3.96	3.98	3.99
86	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.92	3.93	3.95	3.96	3.97	3.99
87	3.80	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.94	3.95	3.97	3.98
88	3.79	3.80	3.81	3.83	3.84	3.85	3.87	3.88	3.89	3.90	3.91	3.93	3.95	3.96	3.97
89	3.78	3.80	3.81	3.82	3.84	3.84	3.86	3.87	3.88	3.89	3.91	3.92	3.94	3.95	3.97
90	3.77	3.79	3.80	3.82	3.83	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.93	3.95	3.96
91	3.76	3.78	3.80	3.81	3.83	3.84	3.84	3.86	3.87	3.88	3.90	3.91	3.92	3.94	3.96
92	3.76	3.77	3.79	3.81	3.82	3.82	3.83	3.85	3.86	3.87	3.89	3.90	3.91	3.93	3.94
93	3.75	3.76	3.78	3.79	3.80	3.82	3.83	3.84	3.86	3.87	3.88	3.89	3.90	3.92	3.93
94	3.75	3.76	3.77	3.78	3.79	3.81	3.82	3.84	3.85	3.86	3.87	3.88	3.90	3.91	3.92
95	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.86	3.88	3.89	3.91	3.92
96	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.84	3.86	3.86	3.87	3.88	3.90	3.91
97	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.84	3.85	3.87	3.87	3.89	3.89	3.90
98	3.72	3.74	3.75	3.76	3.77	3.78	3.80	3.81	3.82	3.83	3.85	3.86	3.87	3.88	3.90
99	3.71	3.73	3.73	3.75	3.77	3.78	3.79	3.80	3.81	3.83	3.84	3.86	3.87	3.88	3.89
100	3.71	3.72	3.72	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.85	3.86	3.87	3.88
101	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.86	3.88
102	3.69	3.70	3.71	3.73	3.74	3.75	3.76	3.78	3.79	3.81	3.82	3.83	3.84	3.85	3.87
103	3.68	3.70	3.71	3.72	3.74	3.75	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85	3.87
104	3.67	3.69	3.70	3.71	3.72	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84	3.86
105	3.67	3.68	3.70	3.71	3.72	3.73	3.74	3.76	3.77	3.79	3.80	3.81	3.83	3.84	3.85
106	3.66	3.68	3.69	3.70	3.72	3.73	3.74	3.76	3.77	3.78	3.79	3.80	3.82	3.83	3.84
107	3.66	3.68	3.68	3.70	3.71	3.72	3.73	3.75	3.76	3.78	3.79	3.80	3.81	3.83	3.84
108	3.65	3.67	3.68	3.69	3.70	3.72	3.73	3.74	3.75	3.77	3.78	3.79	3.80	3.82	3.83

TABLE No. 67

Table Giving Percentages Fast (+) and Slow (−) with Correcting Factors to be Used in Testing Large Capacity Meters with the Funnel Meter. All Figures Given on the Basis of a 1½ in. Orifice Passing One Cubic Foot Per Second at a Four Inch Water Pressure Corrected for Barometer and Thermometer Changes and for Specific Gravity of Gas Used.

Fast Meters			Slow Meters		
Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent Fast (Funnel Meter being Standard)	Correcting Factor. Deduct Meter Reading Per Cent	Time Required by Meter to Register 100 Cu. Ft. in Seconds	Per Cent Slow (Funnel Meter being Standard)	Correcting Factor. Add to Meter Reading Per Cent
100	O. K.	none	100	O. K.	none
99	1 +	1	101	.9 −	1
98	2 +	2	102	1.9 −	2
97	3 +	3	103	2.9 −	3
96	4.1 +	4	104	3.8 −	4
95	5.2 +	5	105	4.7 −	5
94	6.3 +	6	106	5.6 −	6
93	7.5 +	7	107	6.5 −	7
92	8.6 +	8	108	7.4 −	8
91	9.8 +	9	109	8.2 −	9
90	11.1 +	10	110	9. −	10
89	12.3 +	11	111	9.9 −	11
88	13.6 +	12	112	10.7 −	12
87	14.9 +	13	113	11.5 −	13
86	16.2 +	14	114	12.2 −	14
85	17.6 +	15	115	13. −	15
84	19. +	16	116	13.7 −	16
83	20.4 +	17	117	14.5 −	17
82	21.9 +	18	118	15.2 −	18
81	23.4 +	19	119	15.9 −	19
80	25. +	20	120	16.6 −	20
79	26.5 +	21	121	17.3 −	21
78	28.1 +	22	122	18. −	22
77	29.8 +	23	123	18.6 −	23
76	31.5 +	24	124	19.3 −	24
75	33.3 +	25	125	20. −	25
74	35.1 +	26	126	20.6 −	26
73	36.9 +	27	127	21.2 −	27
72	38.8 +	28	128	21.8 −	28

Example;—If a meter passes 100 cubic feet in 80 seconds the meter is 25 per cent fast on a basis of the funnel being standard but the correcting factor being 20, to correct meter reading, deduct 20 per cent.

as much in 100 seconds, or 7,200 cubic feet. This is true of any number of holes open under proper pressure conditions for a period of 100 seconds.

The following is a table of the different capacities of the funnel at proper pressure, where a test is made in using the 100 foot dial, and also in using the 1,000 foot dial:—

TABLE No. 68

Holes open	Volume per hour	Time of test with 100 ft. dial	Volume passed meter in proving with 100 ft. dial	Time of test with 1000 ft. dial		Volume passed meter in proving with 1000 ft. dial
		Sec.	Feet	Min.	Sec.	Feet
1	3,600	100	100	16	40	1,000
2	7,200	100	200	8	20	1,000
3	10,800	100	300	5	33	1,000
4	14,400	100	400	4	10	1,000
5	18,000	100	500	3	20	1,000
6	21,600	100	600	2	46	1,000
8	28,800	100	800	2	5	1,000
10	36,000	100	1,000		100	1,000
12	43,200	100	1,200		100	1,200
14	50,400	100	1,400		100	1,400
16	57,600	100	1,600		100	1,600
18	64,800	100	1,800		100	1,800
20	72,000	100	2,000		100	2,000

Weather Conditions—Tests should not be made during severe wind storms, unless blinds are brought into service to shield the face of the funnel from the full force of the wind. Also tests should not be made during a rain or snow storm.

SPECIFIC GRAVITY

In testing large capacity meters with air, no correction is made on the pressure as selected from the table on pages 410 and 411. In testing with natural gas it is very necessary to take the gravity at least once a day during the test.

Date........................19....

Owner..

....

On......................lease.

No............ Capacity......................M. 50 Pounds Test

Tally No....................

Flange............ Reading after test............Cu. Ft.

" before " .... " "

Measuring at............per hour. Used............ " "

Specific gravity of gas..............

Change Wheel.......... Drive Wheel.......... Chart No........

Funnel Meter Test			Data
Volume per Hour	Preliminary Test	Final Test	
Cu. ft.	%	%	Sp. Grav. of Gas
			Barometer
900			Temperature
1,800			Press. on Funnel
2,700			Tested with
3,600			Air
7,200			Residue
10,800			Casinghead Gas
14,400			Remarks
18,000			
21,600			
28,800			
36,000			
43,200			
50,400			
57,600			
64,800			
72,000			
90,000			
108,000			

Witnessed by

....

Date ....

Inspector

Fig. 146—METER TESTING REPORT

Ordinarily, if the meter is in good condition and has been tested within the previous 60 days, the test would require but one or two hours and one test of the gravity is all that is required.

ADJUSTMENT OF BILLS WHERE METERS ARE FOUND INACCURATE

This is a question that is very often misunderstood or abused. When a meter is tested monthly and left accurate each time, and at the end of one particular month showed an error of 10 per cent. fast, it would not be right to use an adjusting figure of 10 per cent. for that particular month. If a meter is considered O. K. the first of the month and 10 per cent. fast at the end of the month, measuring practically the average volume daily, with no extraordinary conditions having existed, the adjusting percentage should be one-half or 5 per cent. for any month's reading. Meters do not change their accuracy suddenly. It invariably is brought about slowly. For instance, if a certain meter is 1 per cent. fast on the first of the month and found to be 10 per cent. fast at the end of the month, the error in this meter starting out at the first of the month at 1 per cent. would gradually increase from day to day until it reached the full 10 per cent. at the end of the month. Another thing that is seldom considered: for illustration, take a 20,000 foot per hour meter which has been measuring a volume varying from 3,600 feet per hour to 21,600 feet per hour that showed the following error on the different volumes:

3,600	cu. ft. per hour	10 per cent. fast.
7,200	" " " "	6 per cent. fast.
10,800	" " " "	2 per cent. fast.
14,400	" " " "	O. K.
18,000	" " " "	4 per cent. slow.
21,600	" " " "	5 per cent. slow.

This meter should not be called 10 per cent. fast.

The actual average percentage fast would be 1½ per cent. as the error on all volumes should be taken into consideration.

Invariably the greatest error is shown on the smallest volume tested, but this is no reason why that particular figure should be picked out when speaking of the accuracy of the meter unless the meter was working at that capacity continually.

The figure that should be used and taken into consideration is the error of the meter at the volume or volumes that the meter is measuring. While it is desired to have the meter working accurately upon all volumes, it will always be found in any type of meter, domestic, proportional or orifice, measuring gas or liquid, that the greatest error will exist on the small percentages of their rated capacities.

In reading the foregoing, one should not form the opinion that it applies to all meters. It will usually be found that the worst working meters are those that are improperly set or receive the least attention. In the writer's experience in making tests throughout the country for the past many years it was found that about 50 to 60 per cent. of the meters tested were accurate and needed no attention. This of course covered natural as well as casinghead gas.

Large Capacity Meter for Measuring Compressed Air—This meter is a displacement meter and gives meter readings on a clock or a dial in compressed air figures. The capacity of the meter has reference to the meter reading.

If it is desired to reduce meter readings or compressed air figures to free air figures, use the multiplier tables for various pressures on page 434.

If the pressure is variable, a volume and pressure gauge is essential, the same as in measurement of high pressure gas. This records the pressure variations, together with the number of thousands of cubic feet of air passing through the meter at the recorded pressure, from which is com-

puted the corresponding quantity of free air. The gauge will also show the peak and minimum loads during the twenty-four hour period. Gauges are furnished with either twenty-four hour or seven-day clocks.

Do not set a meter near a compressor unless plenty of pipe area is furnished or tanks are installed between the meter and the compressor to eliminate the vibration or throb of the piston. Large capacity meters will stand some vibration but not an excessive amount.

CAUSES OF FAILURES IN MEASURING NATURAL GAS BY PROPORTIONAL OR LARGE CAPACITY METERS

Lack of proper attention.

Meter too small or too large a capacity.

Water, oil or sand in the gas.

To these three causes one can attribute nine-tenths of the inaccuracy and trouble in measuring gas with a proportional or large capacity meter.

Lack of Attention—To the writer this is an old subject. Of course it is much easier to write this, saying what should be done to obtain accuracy than it is to get out and follow the advice, or to spend money to have it done, which means an increase in a company's overhead expense.

The old original types of proportional meters had a general tendency to run slow if neglected. The writer has often stated that more money was lost through slow meters than in drilling dry holes. While this may appear to the reader as rather a strong statement it is based on actual field tests of proportional or large capacity meters made by the author from 1907 to 1910.

In recent years many improvements in large capacity meters have been made and still greater improvement in the attention and care that is given them.

Nearly all large companies employ one or more men to continually look after as well as read their meters.

The meter tester or repair man is just as essential to the gasoline company as the receiving teller is to the bank. The receiving teller receives the money of which he must count and examine or test for genuineness and keep a careful record. It is with this money coming into the bank through the receiving teller's hands that the bank makes its profit.

The meter man should have full charge of the meters, to test, repair and read them and make sure that his employers are receiving 1,000 feet of gas for 1,000 feet of gas paid for. The relative position of these two men is identical.

The meter tester should be a man with experience, preferably with a combination of factory and field experience, the point the writer wishes to bring out is that it is a position of importance and should be filled by a capable and experienced man.

It is hardly necessary to say that there is no set rule that one can lay down governing the frequency of making tests on meters. The writer has already stated in this book that meters should be tested once in two months. Meters have been found that did not need testing but once in 10 months or a year, while others have been found that require testing every 3 or 4 weeks. The frequency of tests should be left to the judgment of the meter tester. By a careful study of the preliminary tests upon any one meter it will show whether the meter is being tested often enough or whether more time may be allowed to elapse between tests.

METERS WITH TOO SMALL OR TOO LARGE A CAPACITY

In selecting a meter to measure gas, due consideration should be given to selecting the proper size. The same reasoning should be applied as in buying an automobile truck. One would not buy a 5-ton truck to haul express packages, nor a 1-ton truck to haul a 5-ton load. It is true that the volume of gas being measured will often vary and the minimum and maximum might have a wide range. In this case the proper size meter should be selected to measure the maximum volume, then if the meter did show an error in measuring the minimum volume, the error in dollars and cents would be a very small factor as compared with what it might be were the meter working over capacity.

In other words, a small error on a large volume of gas would amount to more than a large error on a very small volume. The accuracy at a maximum volume should first be considered. There are no meters made that will carry absolute accuracy, even when new, at volumes ranging from nothing up to the rated capacity of the meter. This statement is true of domestic meters as well as proportional or orifice meters.

If, after installing a meter, it is found that there is not sufficient gas to keep the meter working on the 25 per cent. load or greater, this being the maximum volume that was measured, it is far better to change the size of the meter. Meters are corrected in the factory to work down to an exceptionally low volume, in fact they are tested on a smaller volume in proportion than domestic meters, but they should not be expected to work accurately on this low volume. There are times of course when meters are found to be too large but it would not be profitable to make a change. In this case tests should be made more often to keep the meters in accurate condition.

If one should purchase a certain size compressor, and after installation find that the greatest amount of gas that could be furnished to it was only 10 per cent. of its capacity, he would naturally move the compressor to some other point or exchange it. It would be foolish to keep a compressor only carrying a 10 per cent. load. The foregoing holds true with the measuring of casinghead gas.

WATER, OIL OR SAND IN THE GAS

The Large Capacity or Proportional Meters never were intended to measure water, oil or vapor, likewise they were not intended to act as a sand collector.

Unfortunately, natural gas does not always come from the earth as a pure natural gas, which is true of pure water from a spring on the mountain side.

After natural gas is found by the drill, the company is invariably in a hurry to get it into the line where it can be delivered to a market and bring some return. When this happens it means trouble sooner or later, not only to the meters but to the regulators and gates.

If the field company could appreciate the difference between trying to measure a wet or dirty gas and measuring a dry, clean gas they would certainly overcome many meter troubles.

Even though a well comes in showing a dry, clean gas, provision should be made for the installation of drips of proper capacity and at proper locations along the line from the well to the main line. It might not be necessary to install the drips immediately but by leaving connections for them it would be much easier to go back later and install them.

The author will state that it is impossible to obtain accuracy with any type of meter, either large capacity or orifice, in measuring a wet, dirty gas. Whenever it is attempted the meter reading becomes an approximation unsatisfactory to both the buyer and the seller.

Keep the gas clean and help obtain accuracy regardless of the type of meter in use.

Recording Gauge—Where gas is measured at a greater pressure than four ounces, a recording gauge is necessary to determine the pressure throughout the 24 hours so that the multiplier for the average pressure can be applied to the meter reading to obtain the actual amount of gas passed.

The recording gauge should be set on the meter itself and if it is a 24-hour gauge, the chart should be taken off daily and the day's reading, together with the previous day's reading, written on the back of the chart.

Before setting a recording gauge on a large capacity meter, see that the marking arm rests at zero.

It is very essential to have recording pressure gauges that are used in connection with large capacity meters tested, as an error of ten pounds would amount to from 6 to 8 per cent. in the actual gas passed through the meter at 125 lb. pressure.

VOLUME AND PRESSURE RECORDING GAUGE

Seldom is natural gas or casinghead gas sold in the field at atmospheric or a low pressure. Gases of any nature are compressible. It is not uncommon to measure casinghead gas at as low a pressure as 25 inches of mercury vacuum and natural gas at a pressure as high as 500 pounds. In buying or selling gas there is a recognized low pressure base. While this base varies from atmospheric pressure up to two or three pounds it is generally specified in the purchase agreement or contract.

All large capacity, casinghead or proportional meters are displacement meters and measure in cubic feet of "space" passing the meter, regardless of pressure, consequently meter readings must be reduced or corrected for the density at which the gas is measured. In doing this, tables

of multipliers of various pressure bases will be found in "Measurement of Gas where Density Changes," published by this Company.

The older method of reducing meter readings to a low pressure base is to use a "straight" recording pressure gauge which records pressure only, working independent of the meter index. In using this type of gauge the pressure recorded on the chart for the period of 24 hours is averaged and the multiplier for same is applied to the total meter reading for the day. While this gives a fairly

Fig. 147—VOLUME AND PRESSURE RECORDING GAUGE

accurate service, it does not give as accurate results as will be obtained by using a volume and pressure recording gauge. With the latter type of gauge each 1,000 or 10,000 cu. ft. volume is recorded by a dash opposite its pressure on the chart and the multiplier can be applied to each volume in order to reduce to a low pressure base.

Description—The Volume and Pressure Recording Gauge is a combination of a recording pressure gauge and a special meter index connected to a second pen arm and marking the dash in the allotted space just outside of

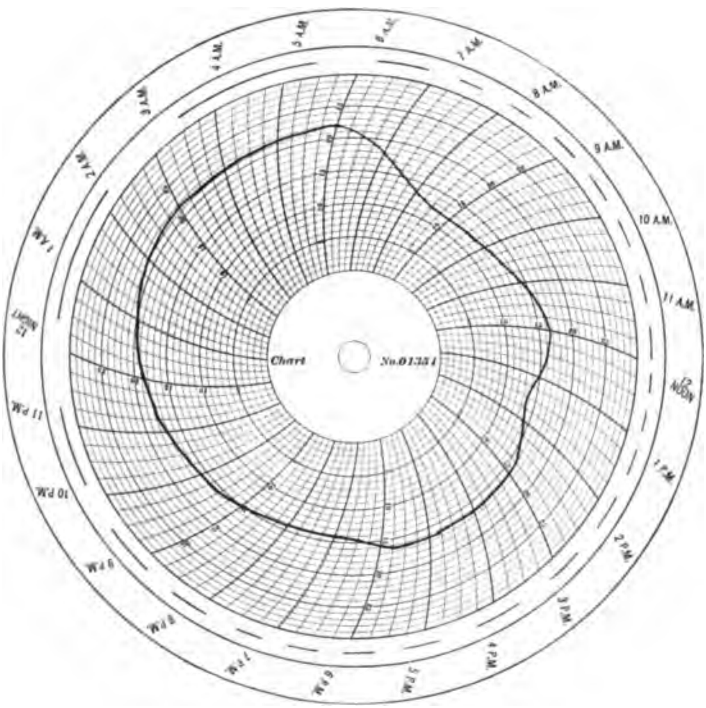


Fig. 148—VOLUME AND PRESSURE RECORDING GAUGE CHART. EACH DASH IN SPACE ADJOINING PRESSURE GRADUATIONS INDICATES A 10,000 CU. FT. VOLUME HAS PASSED THE METER

the pressure graduations on the chart, for each 10,000 or 1,000 feet volume passing the meter and adapted for use on large capacity or proportional meters only.

Gauges for meters of 20,000 cubic feet per hour capacity are usually built with a 10,000 foot pen arm and gauges

furnished for meters of smaller capacity are built with a 1,000 foot pen arm unless otherwise ordered.

When in service on the gas line, if the volume of gas passing the meter is increased, the number of dashes per hour is increased and they become shorter. On the other hand, if the volume of gas is decreased, the dashes become fewer and longer.

The back of the gauge carries a ¼ inch pressure connection which is connected with the tap in the tally cover.

The gauge and index combined are shipped detached from the meter and can be very easily installed after the meter is connected in the line.

Volume and Pressure Gauge Working on High Pressure—Invariably the pressure of gas in a pipe line will vary more or less throughout a 24-hour period. The higher the pressure the greater the density and the larger the multiplier. The lower the pressure the less the density of the gas and the smaller the multiplier. When the pressure reaches the pressure base upon which the gas is bought or sold, the multiplier equals 1 and is ignored.

The volume and pressure dashes on the side of the chart enable one to apply the multiplier to that particular volume instead of averaging the pressure for 24 hours and applying it to the daily meter reading. There may be many dashes on the chart indicating many 10,000 ft. volumes having passed the meter throughout the 24-hour period. With this assistance one is able to apply the correct multiplier to each and every one of the 10,000 ft. volumes and by so doing obtain greater accuracy of the volume of low pressure gas that has passed the meter during any one 24-hour period.

With the aid of this gauge one is able to tell at what hours during the day the greatest volume of gas is measured by the meter or in other words, the time of the peak load.

Should any breaks occur in the line either ahead of or behind the meter, one would be able to tell the time that the

break occurred and should the break be ahead of the meter it will show the volume of gas passed the meter from the time of the break until repaired. This written record is of great value in any case of this kind.

Reading the Volume and Pressure Gauge Chart—The simplest and most accurate way to read this chart is to divide each dash with a pencil mark, as shown in Fig. 149. Then follow the division mark on each dash along the graduation lines and mark the pressure line; in other words,

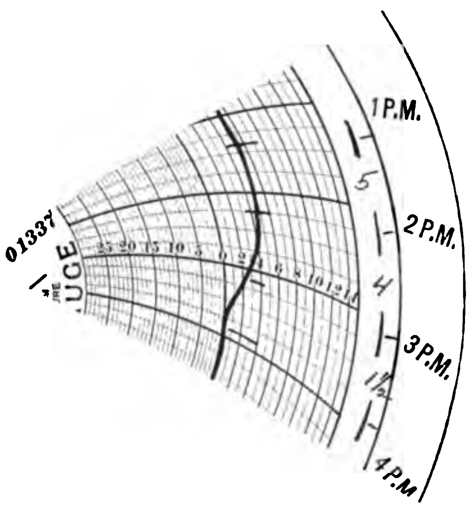


Fig. 149—SEGMENT OF A VOLUME AND PRESSURE CHART SHOWING PRESSURE RECORD, THE VOLUME RECORDED IN 10,000 FOOT DASHES AND PRESSURE AVERAGED OPPOSITE DASHES

Pressure	Volume	Multiplier	Low Pressure Gas Measured
5 lb.	10,000	1.3242	13,242
4 lb.	10,000	1.2559	12,559
1½ lb.	10,000	1.0853	10,853

Pressure Base = 4 oz.

one would be determining the pressure opposite one particular 10,000 ft. volume. Average the pressure between the two marks for each 10,000 ft. volume and find the multiplier in our book entitled "Measurement of Gases Where Density Changes." The multiplier can be written on the chart between the two dashes and after the process is followed out around the whole chart, the multipliers with the decimal set to the right three places can be put on the adding machine and the volume quickly added for the 24 hour measurement, assuming that one is using the 24 hour chart, which is generally the case.

The total amount of gas measured as figured by the 10,000 ft. dashes can then be checked with the difference between the daily meter reading as taken by the index, and reduced to low pressure by the common method of averaging the pressure for 24 hours and using one multiplier on the total meter reading for the same period. This however, is not absolutely necessary but can be used as a check method if desired.

It will be found in computing a series of these charts that invariably part of the last 10,000 ft. volume reduced will fall upon the following day's chart. In this case it will be necessary to take into consideration the pressure for that part of the 10,000 ft. volume that falls on the following day's chart, in consequence of which the actual amount of low pressure gas as figured by the dash method will check within 10,000 cu. ft. of the old method of using the planimeter on the 24 hour pressure chart and multiplying the meter reading by the multiplier for the average pressure as shown by the planimeter. This corrects itself from day to day. The reducing of meter readings, either under high pressure or at a vacuum, to a low pressure base with the assistance of the volume and pressure gauge, is more accurate than the old method of averaging the pressure for each 24 hours and then using one multiplier on the meter reading.

The volume marking arm of this gauge carries a flexible joint which can be bent one way or the other so that the dash will fall within the allotted space on the side of the chart. In shipping, sometimes the pen arm will become bent so it makes the dash outside of the allotted space where it is more difficult to read and in addition might interfere with the pressure marking arm.

Ordering Volume and Pressure Gauges for Meters Already Installed—When ordering give the following information:

1. The number and capacity of the meter.
2. The pressure range.
3. Size of chart—8 inch or 12 inch.
4. Time of chart—24 hour or 7 day.

As the various size meters carry various percentage clocks it is necessary that the size of the meter be stated in order that we may equip the gauge with the correct index. The number of the meter is also necessary to enable us to determine what change wheel was on the index when it left the factory.

The pressure range of the gauge should be selected so that it will work between 25 per cent. and 75 per cent. of its maximum pressure.

Gauges are made to carry 8 inch or 12 inch charts. The 12 inch charts give larger graduations for the same pressure and are easier to read.

Gauge clocks and charts are made for 24 hour and 7 day time periods.

TABLE No. 69
PRESSURE EQUIVALENTS

Ounces	In. Water	In. Mercury	In. Mercury	Ounces	In. Water	In. Water	In. Mercury	Ounces
.25	.43	.032	1.	7.85	13.60	.25	.018	.144
.50	.87	.064	1.5	11.78	20.40	.50	.037	.259
.75	1.30	.095	2.	15.71	27.20	.75	.055	.433
1.	1.73	.127	2.5	1.23 lb.	34.00	1.	.073	.577
2.	3.46	.26	3.	1.47 "	40.80	2.	.147	1.15
3.	5.19	.38	3.5	1.72 "	47.60	3.	.22	1.73
4.	6.92	.51	4.	1.96 "	54.40	4.	.29	2.31
5.	8.65	.64	4.5	2.21 "	61.20	5.	.37	2.89
6.	10.38	.77	5.	2.45 "	68.00	6.	.44	3.46
7.	12.11	.89	5.5	2.74 "	74.80	7.	.51	4.04
8.	13.85	1.02	6.	2.94 "	81.60	8.	.59	4.62
9.	15.58	1.15	6.5	3.19 "	88.40	9.	.66	5 20
10.	17.31	1.27	7.	3.44 "	95.20	10.	.74	5.77
11.	19.05	1.40	7.5	3.68 "	102.00	11.	.81	6.35
12.	20.78	1.53	8.	3.93 "	108.80	12.	.88	6.93
13.	22.51	1.66	8.5	4.17 "	115.61	13.	.96	7.51
14.	24.24	1.78	9.	4.42 "	122.41	14.	1.03	8.08
15.	25.97	1.91	9.5	4.66 "	129.21	15.	1.10	8.66
16 or 1 lb.	27.71	2.04	10.	4.91 "	136.01	16.	1.18	9.24
1 lb. 1 oz.	29.44	2.16	10.5	5.15 "	142.81	17.	1.25	9.82
" 2 "	31.17	2.29	11.	5.40 "	149.61	18.	1.32	10.39
" 3 "	32.90	2.42	11.5	5.64 "	156.41	19.	1.40	10.97
" 4 "	34.63	2.55	12.	5.89 "	163.21	20.	1.47	11.55
" 5 "	36.36	2.67	12.5	6.14 "	170.01	21.	1.54	12.13
" 6 "	38.09	2.80	13.	6.38 "	176.81	22.	1.62	12.70
" 7 "	39.82	2.93	13.5	6.63 "	183.61	23.	1.69	13.28
" 8 "	41.56	3.06	14.	6.87 "	190.41	24.	1.76	13.86
" 9 "	43.29	3.18	14.5	7.12 "	197.21	25.	1.84	14.44
" 10 "	45.02	3.31	15.	7.36 "	204.01	26.	1.91	15.01
" 11 "	46.76	3.44	15.5	7.61 "	210.81	27.	1.99	15.59
" 12 "	48.49	3.57	16.	7.85 "	217.61	27.71	2.04	16 or 1 lb.
" 13 "	50.22	3.69	16.5	8.10 "	224.41	29.	2.13	1.05 lb.
" 14 "	51.95	3.82	17.	8.34 "	231.21	30.	2.21	1.08 "
" 15 "	53.68	3.95	17.5	8.59 "	238.01	31.	2.28	1.12 "
2 lb.	55.42	4.07	18.	8.83 "	244.81	32.	2.35	1.15 "
2 lb. 1oz.	57.15	4.20	18.5	9.08 "	251.61	33.	2.43	1.19 "
" 2 "	58.88	4.33	19.	9.33 "	258.41	34	2.50	1.23 "
" 3 "	60.62	4.46	19.5	9.57 "	265.21	35.	2.57	1.26 "
" 4 "	62.35	4.59	20.	9.82 "	272.01	36.	2.65	1.30 "
" 5 "	64.08	4.71	20.5	10.06 "	278.81	37.	2.72	1.34 "
" 6 "	65.81	4.84	21.	10.31 "	285.61	38.	2.79	1.37 "
" 7 "	67.54	4.97	21.5	10.55 "	292.41	39.	2.87	1.41 "
" 8 "	69.27	5.10	22.	10.80 "	299.21	40.	2.94	1.44 "
" 9 "	71.01	5.22	22.5	11.04 "	306.01	41.	3.01	1.48 "
" 10 "	72.74	5.35	23.	11.29 "	312.81	42.	3.09	1.52 "
" 11 "	74.47	5.48	23.5	11.53 "	319.61	43.	3.16	1.55 "
" 12 "	76.20	5.60	24.	11.78 "	326.41	44.	3.24	1.59 "
" 13 "	77.93	5.73	24.5	12.02 "	333.21	45.	3.31	1.62 "
" 14 "	59.67	5.86	25.	12.27 "	340.02	46.	3.38	1.66 "
" 15 "	81.40	5.99	25.5	12.52 "	346.82	47.	3.46	1.70 "
3 lb.	83.13	6.11	26.	12.76 "	353.62	48.	3.53	1.73 "
" 1oz.	84.86	6.24	26.5	13.01 "	360.42	49.	3.60	1.77 "
" 2 "	86.59	6.37	27.	13.25 "	367.22	50.	3.68	1.80 "
" 3 "	88.33	6.50	27.5	13.50 "	374.02	51.	3.75	1.84 "
" 4 "	90.06	6.62	28.	13.74 "	380.82	52.	3.82	1.88 "
" 5 "	91.79	6.75	28.5	13.99 "	387.62	53.	3.90	1.91 "
" 6 "	93.52	6.88	29.	14.23 "	394.42	54.	3.97	1.95 "
" 7 "	95.65	7.01	29.5	14.48 "	401.22	55.42	4.07	2. lb.
" 8 "	96.98	7.13	30.	14.72 "	408.02			

PART NINE

DENSITY OF GASES

Robert Boyle—Robert Boyle was an English natural philosopher, the seventh son and the fourteenth child of Richard Boyle, the great Earl of Cork. He was born at Lismore Castle, province of Munster, Ireland, January 25, 1627.

After three years at Eton he went abroad to travel with a French tutor. Returning to England in 1642 he found his father had died and left him estates at Dorsetshire and in Ireland. From that time on he gave his life to study.

Reading, in 1657, of Otto von Guericke's air pump, he set himself, with the assistance of Robert Hooke, to devise improvements in its construction. The pneumatic engine being finished in 1659, he began a series of experiments on the properties of air. An account of the work he did with this instrument was published in 1660 under the title "New Experiments Physico-Mechanical Touching the Spring of Air and Its Effects."

Among the critics of the views put forward in the book was a Jesuit, Franciscus Linue; and it was while answering his objections that Boyle enunciated the law that the "volume of gas varies inversely as the pressure." This law among English-speaking people, is called after his name; though on the continent it is attributed to E. Mariotte, who did not publish it till 1676.

Robert Boyle died December 30, 1691, at the house of his sister in Pall Mall, London.

Edmond Mariotte—The French physicist, Edmond Mariotte, was born in 1620 at Dijon, where he spent most of his life. He was one of the first members of the Academy of Science, founded in Paris in 1666. He died in Paris, May 12, 1684.

He wrote many essays between 1676 and 1679 bearing on physical subjects, such as motion of fluids, freezing water, and the barometer.

In his second essay, written about 1676, is the statement of the law that the "volume varies inversely as the pressure," which, though very generally called by his name, had been discovered by Robert Boyle in 1660.

Jacques Alexander Cesar Charles—Jacques Alexander Cesar Charles was a French mathematician and physicist, born in Beaugency, Loiret, November 12, 1746. He was the first to employ hydrogen for the inflation of balloons, and in about 1787 he anticipated Gay Lussac's law of dilation of gases with heat, which, on that account, is sometimes known by his name.

He died in Paris, April 7, 1823.

Boyle's and Mariotte's Law—In a perfect gas the volume is inversely proportional to the pressure to which the gas is subjected, or, what is the same thing, the product of the pressure and the volume of a given quantity of gas remains constant.

Charles' Law—The volume of a given mass of any gas, under constant pressure, increases from the freezing point by constant fraction of its volume at zero. In other words, gases expand $\frac{1}{273}$ of their volume at 0 deg. C. for each deg. of C. rise of temperature, and $\frac{1}{492}$ of their volume at 32 deg. fahr. for each deg. fahr. rise of temperature.

Expansion or Contraction of Natural Gas Due to Change in Temperature—All perfect gases expand or contract $\frac{1}{492}$ or 0.00203 of their volume at 32 deg. fahr. for an increase or decrease, respectively, of each deg. fahr. of temperature. Consequently if the temperature should fall 492 deg. below

freezing temperature, or 460 deg. below zero, fahr., the volume of gas would contract to nothing. This point, minus, 460 deg. fahr., is called the absolute zero of temperature, and the absolute temperature of any gas is its temperature above freezing plus 460 deg. Thus 60 deg. standard temperature corresponds to $60 + 460 = 520$ deg. absolute temperature.

Low Pressure Basis—The "Rock Pressure" of gas wells varies according to the depth of the well and the length of time the well has been drilled; likewise the pressure of the flowing gas in pipe lines, meters, regulators, and gates is extremely variable, and on account of this variation in pressure, it was found necessary to establish some basis on which to sell and buy natural gas.

Some years ago Mr. F. H. Oliphant, at that time of the United States Geological Survey, considered as a basis of natural gas measurement a pressure of 14.65 pounds per square inch absolute, and a temperature of 60 degrees fahr., and since then it has become customary for natural gas men to refer their gas measurements to this basis A pressure of 14.65 pounds per square inch is 4 ounces above the assumed atmospheric pressure of 14.4 pounds per square inch, the latter being the average at about the elevation of the Great Lakes, which elevation was considered to fairly represent that of most gas fields.

Density Changes in Gas Volumes—At 4-ounce pressure a cubic foot of gas is made up of a certain number of atoms. In order to increase the pressure in a cubic foot of gas confined into a like space, it is necessary to force into that space more gas or more atoms of gas. If a sufficient amount of gas is forced into the confined space, originally holding a cubic foot of gas at 4 ounce pressure, to create 15 pounds pressure, there will then be twice as much gas, or twice as many atoms of gas, confined in the same space.

To illustrate, take a cylinder of proper diameter to contain one cubic foot of space for each foot in length fitted with a tight plunger.

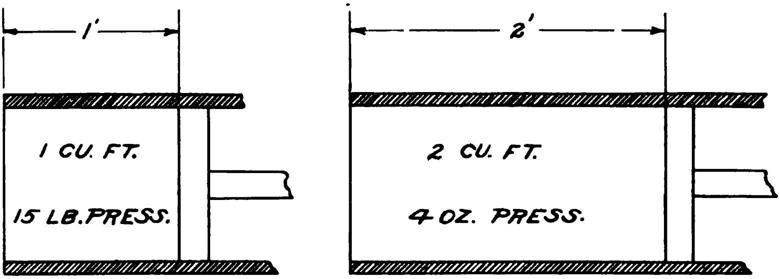


Fig. 160—NOTE—Pressures shown in Charts are Gauge Pressures

If the plunger in the cylinder is placed at the one-foot mark and enough gas forced into the space to create a pressure of fifteen pounds, it could be said that the cylinder contained one cubic foot of 15-pound gas. Then if the plunger is withdrawn until it rests at the two-foot mark the gas will expand and the pressure will drop to four ounces and the actual volume contained in the space will be two cubic feet. In other words, by multiplying the cubic contents in the first cylinder by 2 it will give the actual amount of 4-ounce gas in cubic feet.

As all gas meters in the factory are tested and corrected to a low pressure basis, measuring gas by displacement, they may be compared to the cylinder with the plunger as illustrated above. In measuring gas in the meter, the diaphragms contain just so much space. If the pressure of the gas confined in each quantity or volume of gas measured by the diaphragms filling and discharging is four ounces, then the meter reading needs no correction; but each time the meter diaphragm fills and discharges a volume of gas at a higher pressure than four ounces, the meter reading must be corrected by applying a multiplier, to reduce the volume of

gas measured to a four-ounce basis; and the higher the pressure the greater will be the density of the gas and the greater the number of atoms contained in each cubic foot of space.

The multipliers for density are based on Boyle's law, written in 1660, that the "volume of a gas varies inversely as the pressure."

While the four ounce basis is generally accepted when no other pressure basis is stated in a buying and selling agreement, some other basis can be used and very often is used, particularly when gas is bought or sold in large volumes in the field.

Formula for Determining the Quantity of Natural Gas When Measured Above Normal Pressure—In which

$$Q = q\frac{p+h}{h+.25}$$

Q = cubic feet required.
q = cubic feet shown by meter.
p = gauge pressure in pounds.
h = atmospheric pressure of 14.4 pounds.
0.25 = 4-ounce pressure reduced to pounds.

By substituting the known values in the above it becomes

$$Q = q\frac{p+14.4}{14.65}$$

FOR EXAMPLE:—Suppose the meter or q reads 1,000 cubic feet and the pressure p shows 32½ pounds to the square inch, required to find the quantity of gas at a pressure of four ounces. Then

$$Q = 1{,}000\frac{32.5+14.4}{14.65} = 3.2013 \times 1000 = 3{,}201.3$$

Multipliers are given on the following pages for 4-ounce basis in pressures up to 250 lbs. Multiplier tables for all pressure bases and up to 500 lb. pressure are given in the "Measurement of Gas where Density Changes" published by this Company.

TABLE No. 70—Multipliers for Reducing Gas Volumes or Meter Readings to a Pressure Base of 4 Ounces Above Atmospheric Pressure. Atmospheric Pressure Taken at 14.4 Lb. per Sq. In.

Gauge Pressure Inches of Mercury	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
—25	.14535	7	1.46075	28	2.89419
—24	.17885	7½	1.49488	28½	2.92832
—23	.21236	8	1.52901	29	2.96245
—22	.24586	8½	1.56313	29½	2.99658
—21	.27936	9	1.59726	30	3.03071
—20	.31287	9½	1.63139	30½	3.06484
—19	.34637	10	1.66552	31	3.09879
—18	.37987	10½	1.69965	31½	3.13310
—17	.41338	11	1.73378	32	3.16723
—16	.44688	11½	1.76791	32½	3.20136
—15	.48038	12	1.80204	33	3.23549
—14	.51389	12½	1.83617	33½	3.26962
—13	.54739	13	1.87030	34	3.30375
—12	.58090	13½	1.90443	34½	3.33788
—11	.61440	14	1.93856	35	3.37201
—10	.64790	14½	1.97269	35½	3.40614
— 9	.68141	15	2.00682	36	3.44027
— 8	.71491	15½	2.04095	36½	3.47440
— 7	.74841	16	2.07508	37	3.50853
— 6	.78191	16½	2.10921	37½	3.54266
— 5	.81542	17	2.14334	38	3.57679
— 4	.84892	17½	2.17747	38½	3.61092
— 3	.88242	18	2.21160	39	3.64505
— 2	.91593	18½	2.24573	39½	3.67918
— 1	.94943	19	2.27986	40	3.71331
Atmos.	.98293	19½	2.31399	40½	3.74744
Lb. per Sq. In.		20	2.34812	41	3.78156
0¼	1.00000	20½	2.38225	41½	3.81569
0½	1.01706	21	2.41638	42	3.84982
1	1.05119	21½	2.45051	42½	3.88395
1½	1.08532	22	2.48464	43	3.91808
2	1.11945	22½	2.51877	43½	3.95221
2½	1.15358	23	2.55290	44	3.98634
3	1.18771	23½	2.58703	44½	4.02047
3½	1.22184	24	2.62116	45	4.05460
4	1.25597	24½	2.65528	45½	4.08873
4½	1.29010	25	2.68941	46	4.12286
5	1.32423	25½	2.72354	46½	4.15699
5½	1.35836	26	2.75767	47	4.19112
6	1.39249	26½	2.79180	47½	4.22525
6½	1.42662	27	2.82593	48	4.25938
		27½	2.86006	48½	4.29351

— Means "Vacuum" or minus pressure

TABLE No. 70—4-Ounce Multipliers—*Continued.*

Gauge Pressure Lb per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density	Gauge Pressure Lb. per Sq. In.	Multiplier or Density
49	4.32764	70	5.76109	91½	7.22866
49½	4.36177	70½	5.79522	92	7.26279
50	4.39590	71	5.82935	92½	7.29692
50½	4.43003	71½	5.86348	93	7.33105
51	4.46416	72	5.89761	93½	7.36518
51½	4.49829	72½	5.93174	94	7.39931
52	4.53242	73	5.96587	94½	7.43344
52½	4.56655	73½	6.00000	95	7.46757
53	4.60068	74	6.03412	95½	7.50170
53½	4.63481	74½	6.06825	96	7.53583
54	4.66894	75	6.10238	96½	7.56996
54½	4.70307	75½	6.13651	97	7.60409
55	4.73720	76	6.17064	97½	7.63822
55½	4.77133	76½	6.20477	98	7.67235
56	4.80546	77	6.23890	98½	7.70648
56½	4.83959	77½	6.27303	99	7.74061
57	4.87372	78	6.30716	99½	7.77474
57½	4.90784	78½	6.34129	100	7.80887
58	4.94197	79	6.37542	101	7.87713
58½	4.97610	79½	6.40955	102	7.94539
59	5.01023	80	6.44368	103	8.01365
59½	5.04436	80½	6.47781	104	8.08191
60	5.07849	81	6.51194	105	8.15107
60½	5.11262	81½	6.54607	106	8.21843
61	5.14675	82	6.58020	107	8.28668
61½	5.18088	82½	6.61433	108	8.35494
62	5.21501	83	6.64846	109	8.42320
62½	5.24914	83½	6.68259	110	8.49146
63	5.28327	84	6.71672	111	8.55972
63½	5.31740	84½	6.75085	112	8.62798
64	5.35153	85	6.78498	113	8.69624
64½	5.38566	85½	6.81911	114	8.76450
65	5.41979	86	6.85324	115	8.83276
65½	5.45392	86½	6.88737	116	8.90102
66	5.48805	87	6.92150	117	8.96928
66½	5.52218	87½	6.95563	118	9.03754
67	5.55631	88	6.98976	119	9.10580
67½	5.59044	88½	7.02389	120	9.17406
68	5.62457	89	7.05802	121	9.24232
68½	5.65870	89½	7.09215	122	9.31058
69	5.69283	90	7.12627	123	9.37883
69½	5.72696	90½	7.16040	124	9.44709
		91	7.19453	125	9.51535

DEVIATION OF NATURAL GAS FROM BOYLE'S LAW

During recent years considerable investigation has been made by G. A. Burrell, formerly of the Bureau of Mines, and by S. S. Wyer, of Columbus, Ohio, on the subject of deviation of natural gas from Boyle's Law. Both Mr. Burrell and Mr. Wyer show very similar results, which seriously affect the accuracy of measurement of natural gas at high pressures. The figures shown in their results apply directly to the tables of multipliers which in turn consist of the formula for Boyle's Law worked out for each pound pressure through any pressure range.

While admitting that these errors in Boyle's Law exist due to the gas not being an ideal gas, it is impossible for the author to give here a table of correcting factors that could be used in the measurement of any gas, as their analyses throughout the gas fields vary so greatly.

The greater the percentage of higher hydrocarbons in natural gas the greater the deviation from Boyle's Law.

If gas were composed of methane only there would be but one correcting factor required, and orifice meter and large capacity meter readings could be easily corrected to one hundred per cent. accuracy when reduced to low-pressure gas volumes.

The constituents in natural gas vary greatly in different fields. Seldom will one find two analyses from different fields alike.

If natural gas is found in proximity to an oil field or strata, it may be expected that the analyses of it will change as the field becomes older and the pressure of the wells decreases. The analyses of gas from some fields have been known to change in a few months' time. No doubt, while a great many gas companies, who are now selling gas at high pressure with displacement or orifice meters, realize that they are not receiving full value for the gas sold, it can not be said to be due to any dishonest intention on the part of the

purchaser, who as a rule furnishes the meters but should be looked upon as a subject with which most gas companies are unfamiliar. The only solution to the problem is to have an analysis made of the gas measured or a practical test made similar to the one described on pages 439 to 445, and from it a correcting factor can be obtained with which to correct the meter readings. This correcting factor can be applied to either the meter (low-pressure) reading or to the gas bill, provided the pressure remains within a certain range. It must be understood that the error is not constant for all pressures but increases as the pressure of the gas increases. To illustrate this, on page 444 is shown a chart of tests made with Pittsburgh gas. If in measuring this gas with a large capacity or displacement meter at 100 lb. pressure the error will be about 2.75 per cent., and if measuring the same gas at a pressure of 375 lb. the error will be about 11 per cent. In other words, the multipliers would reduce the meter readings to 89 per cent. of the actual amount of low pressure gas passed the meter.

In the following table the percentages of error for various pressures are given. These apply to the Pittsburgh gas only or to any gas that would show a similar analysis when measured with a displacement meter.

TABLE No. 71

Pressure lb. per sq. in.	Error in per cent of gas measured as shown in meter readings reduced to low pressure by application of multipliers.
50	— 1¼
100	— 2¾
200	— 5½
300	— 8½
400	—11½

This table is given as an illustration only and does not apply to all gases. It best illustrates how the percentages of

error increase with the pressure. With some gases the error is even greater than shown above and with other gases it is less.

The table given above applies to large capacity or displacement meter readings reduced to low pressure. The error would be one-half of this where orifice meters are used.

If one has the gas analyzed or a practical test made, a correcting factor can be obtained for various pressure ranges and this can be applied to the multipliers. If the pressure of measured gas does not vary but little, the correcting factor could be applied directly to the meter readings after they were reduced to low pressure, or directly to the gas bill in dollars and cents. This can only be done when the pressure varies but little.

This entire subject reminds one of the conditions surrounding the price of wheat. It is generally stated that the price of wheat is $2.25 per bushel. The fact is, it is f. o. b. Chicago, and when the farmer in Kansas sells wheat he obtains that price less the freight. The one in Illinois actually gets more for his wheat than the one in Kansas as he is nearer the market. There are hundreds of different prices of wheat due to the fact that the government set the price f. o. b. Chicago.

If a farmer wishes to know what his wheat will bring him he must take into consideration the freight rate from the nearest shipping point to Chicago.

It is suggested that the gas producer measure the gas at as low a pressure as possible and thus either reduce the possible error or eliminate it.

The error for either type of meter where gas is measured below 100 lb. is not a serious factor. When gas is measured above that pressure the gas producer should give the subject careful attention and study.

THE COMPRESSIBILITY OF NATURAL GAS AT HIGH PRESSURES

By G. A. BURRELL and I. W. ROBERTSON

Introduction—In the course of its examination of samples of natural gas from many different gas fields throughout the country the Bureau of Mines has conducted various special researches in order to ascertain with exactness the composition or physical properties of certain of the samples or to determine the bearing of the facts on larger problems involved in the transportation and use of the gas. This paper treats of an investigation of the compressibility, at pressures up to 35.5 atmospheres, of the natural gas supplied to the city of Pittsburgh and points out the bearing of the results on the measurement of natural gas at high pressures.

The compressibility of the different paraffin hydrocarbon gases that are found in natural gas and of samples of natural gas from different places in the United States will be shown in a subsequent publication.

Composition of Natural Gas—Analysis of the "dry" natural gas used at Pittsburgh by the fractionation method described in Technical Paper 104* gave the following results:

COMPOSITION OF THE NATURAL GAS OF PITTSBURGH

Constituents	Per cent
Methane (CH_4)	84.7
Ethane (C_2H_6)	9.4
Propane (C_3H_8)	3.0
Butane (C_4H_{10}), chiefly	1.3
Nitrogen (N_2)	1.6
	100.0

The results are stated on the basis of water-free gas. The actual water-vapor content, by volume, of the samples the authors tested by passing them over phosphorus pentoxide was 0.7 per cent.

* Burrell, G. A., Seibert, F. M., and Robertson, I. W., Analysis of natural gas by fractional distillation at low temperatures and pressures: Tech. Paper 104, Bureau of Mines, 1915, pp. 8 to 20.

The natural gas used in Pittsburgh is typical of that supplied to many cities in Pennsylvania, Ohio, West Virginia, and other States, as is shown in the following table of analyses. Hence the authors believed that the determination of its compressibility would be of value for application to the measurement of a great deal of natural gas.

The compositions of the natural gas used in eight cities in the United States are as follows:

TABLE No. 72

COMPOSITION OF THE NATURAL GAS FROM DIFFERENT CITIES*

City	CO_2	CH_4	C_2H_6	N_2	Total
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Pittsburgh, Pa	Trace.	79.2	19.6	1.2	100.00
Louisville, Ky	"	77.8	20.4	1.8	100.00
Buffalo, N. Y	"	79.9	15.2	4.9	100.00
Cincinnati, Ohio	"	79.8	19.5	.7	100.00
Cleveland, Ohio	"	80.5	18.2	1.3	100.00
Springfield, Ohio	"	80.3	14.7	5.0	100.00
Columbus, Ohio	"	80.4	18.1	1.5	100.00
Chelsea, Okla	"	75.4	17.7	6.6	100.00

* Burrell, G. A., and Oberfell, G. G., The composition of natural gas used in 25 cities: Tech. Paper 109, Bureau of Mines, 1915, p. 7.

These analyses were made by the ordinary combustion method and hence show only the two predominating paraffin hydrocarbons.*

Compressibility of Methane—The compressibility of methane has been worked out by Amagat† for pressures from 39 atmospheres to 290 atmospheres. His results are shown in Fig. 152 in which the curve has been extrapolated from 39 atmospheres (his lowest observation) to 1 atmosphere. This extrapolation is merely approximate and the authors are now determining by experiment the actual compressibility of methane at pressures less than 39 atmospheres.

Methane is about 9 per cent more compressible at 40 atmospheres and about 17 per cent. more compressible at

* See Burrell, G. A., and Seibert, F. M., The sampling and examination of mine gases and natural gas: Bull. 42, Bureau of Mines, 1913, p. 80.

† Landolt and Bornstein, Physikalisch-chemische Tabellen 1905, p. 65.

100 atmospheres than at 1 atmosphere. The compressibility of the other gaseous constituents of natural gas, such as ethane, propane and butane, has not been determined. These constituents deviate more from Boyle's law than does methane, and hence make natural gas more compressible than if it consisted of methane alone.

Experiments Made — Description of Apparatus — The apparatus with which the authors performed their work is shown in Fig. 151, and was made at the Pittsburgh experiment station of the bureau by O. P. Hood, chief mechanical engineer, W. F. Haustein, instrument maker, and F. E. Donath, glass blower.

The reservoir *a*, contains mercury, which can be forced into the tubes *c*, *d*, and *e* by screwing up the plunger *b* One of the tubes *e*, served as a high-pressure, and another, *d*,as a low-pressure air manometer. The tube *c* contained the natural gas, the compressibility of which was to be measured.

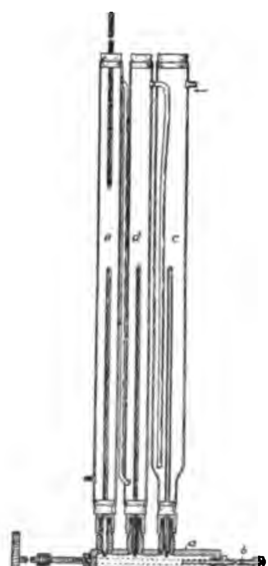


Fig. 151—APPARATUS FOR DETERMINING COMPRESSIBILITY OF NATURAL GAS

Each tube was calibrated by inserting in it a small thread of weighed mercury and forcing this along the entire graduated portion. The volume of this mercury having been calculated from the weight, the bore of the tube through its length was easily determined.

The two air manometers were calibrated to serve as pressure gauges, the low-pressure manometer being calibrated against a long, open tube manometer and the high pressure manometer against the low pressure manometer.

Table No. 73—PV Values for Air with Different Manometers

WITH GAS MANOMETER

Volume	Pressure	PV	Volume	Pressure	PV
c. c.	Mm. of mercury		c. c.	Mm. of mercury	
0.4804	841	404.0	0.2312	1,737	401.6
.4743	852	404.1	.1888	2,128	401.8
.4676	865	404.5	.1504	2,678	402.8
.3882	1,041	403.8	.1167	3,442	401.7
.3358	1,195	401.3	.04812	8,334	401.0
.2853	1,416	403.9	.01251	32,153	402.2
WITH LOW PRESSURE MANOMETER					
0.5119	857	438.7	0.3646	1,200	437.5
.5045	870	438.9	.3499	1,255	439.2
.4971	883	438.9	.3235	1,359	439.6
.4897	897	439.3	.3083	1,430	440.9
.4749	924	438.8	.2931	1,502	440.2
.4455	983	437.9	.2779	1,584	440.2
.4235	1,038	439.6	.2624	1,677	440.0
.3940	1,112	438.1	.2470	1,782	440.2
.3793	1,160	440.0	.2393	1,839	440.1
WITH HIGH PRESSURE MANOMETER					
0.4784	2,035	973.6	0.3620	2,691	974.0
.4532	2,155	976.7	.3363	2,897	974.4
.4272	2,283	975.3	.3236	3,015	975.6
.4141	2,349	972.7	.3109	3,133	973.9
.4011	2,426	972.8	.2982	3,261	972.5
.3881	2,509	973.7	.2484	3,911	971.2

Compressibility of Air—The pressure-volume (PV) values for air with the high and low pressure manometers and with the gas manometer are shown in Table 73. In other words, PV for air was a constant within the error of experimentation, and within its determined deviation from Boyle's law. This provided a good check on the accuracy of the tube calibrations and pressure readings.

Compressibility of Natural Gas Used in Pittsburgh—Table 74 gives the PV products as determined for the natural gas of Pittsburgh, and shows that the gas is more compressible than an ideal gas. A correction has been applied for the compressibility of air.*

* Travers, M. W., The experimental study of gases, 1901, p. 167.

TABLE No. 74—PV Values For Natural Gas

Trial 1.								Trial 2			
Volume	Pressure	PV (relative)	Correction	Volume	Pressure	PV (relative)	Correction	Volume	Pressure	PV (relative)	Correction
c. c.	Mm. of mercury		Per cent.	c. c.	Mm. of mercury		Per cent.	c. c.	Mm. of mercury		Per cent.
0.4801	893	428.7	99.9	0.02886	13,836	399.3	92.5	0.4821	892	429.6	99.9
.3509	1,220	428.1	99.8	.02634	15,078	397.2	92.0	.3228	1,329	429.0	99.8
.2823	1,506	425.1	99.2	.02372	16,557	392.7	90.8	.2154	1,966	423.5	98.6
.2013	2,098	422.3	98.4	.02111	18,353	387.4	89.6	.1936	2,184	422.8	98.3
.1532	2,749	421.1	98.1	.01983	19,416	385.0	88.9	.1536	2,741	421.0	97.7
.1150	3,642	418.8	97.5	.01852	20,605	381.6	88.2	.1153	3,638	419.5	97.4
.09143	4,569	417.7	97.2	.01719	21,969	377.6	87.2	.06252	6,633	410.6	95.4
.07554	5,510	416.2	96.9	.01601	23,466	375.6	86.6	.04678	8,763	409.9	95.0
.05961	6,938	413.6	96.2	.01470	25,346	372.3	85.7	.02378	16,513	392.7	90.7
.04665	8,785	409.8	95.1	.01345	27,467	369.4	85.0	.01854	20,540	380.8	87.7
.03924	10,428	409.2	94.9	....	....	....	....	.01611	23,450	377.8	86.8
.03398	11,891	404.0	93.7	....	....	....	....	.01356	27,390	371.4	85.2

The results given in Table 74 are plotted in Fig. 152. The curve shows the greater compressibility of the natural gas at different pressures, as compared with an ideal gas.

As to the application of these results, the reader should note that sometimes natural gas is measured at pressures as high as 40 atmospheres (about 600 pounds per square

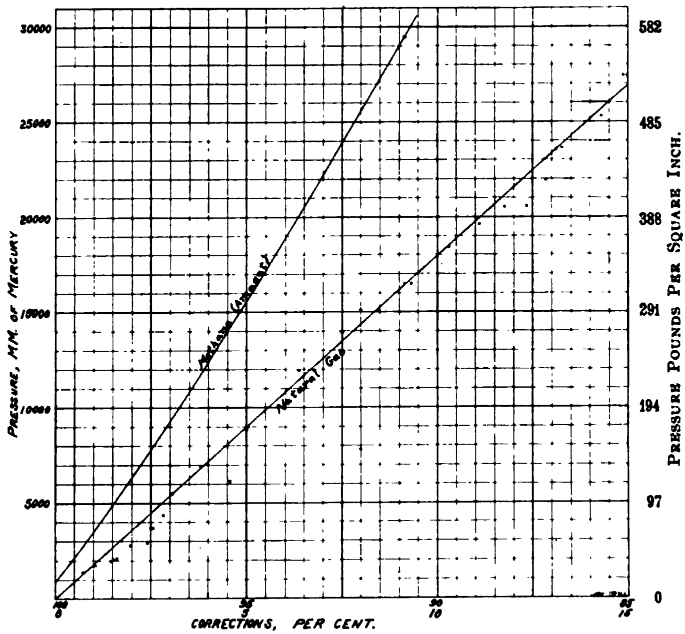


Fig. 152—Compressibility of the natural gas of Pittsburgh, and of methane. Methane curve plotted from results of experiments by Amagat.

inch) and that many millions of cubic feet are measured at pressures of 20 to 30 atmospheres (300 to 450 pounds per square inch). In computing the volume of gas the assumption is always made that Boyle's law applies; that is, that the product of pressure and volume is a constant at all pressures. Hence in measurements under high pressure the error intro-

duced is of great magnitude. For instance, suppose 100,000,000 cubic feet of gas a day is measured at 375 pounds pressure (25.6 atmospheres). According to Fig. 152, the gas is 11 per cent more compressible at 375 pounds (25.6 atmospheres) than at atmospheric pressure. This means that each day 11,000,000 more cubic feet of gas is measured than is supposed. If no correction is applied in measuring the gas, a distributing company that buys natural gas at high pressure and sells it at low pressure may sell much more gas than it pays for.

Summary—The compressibility of the natural gas of Pittsburgh differs from that of an ideal gas, the deviation amounting to as much as 15 per cent at a pressure of 35.5 atmospheres. The results are of practical value, because in measuring natural gas it is the practice to assume that the product of the pressure by the volume is a constant.

PART TEN

REGULATION OF GAS

REGULATORS: HIGH, INTERMEDIATE AND LOW—REGULATOR DIAPHRAGM—REGULATORS AND PLAIN END PIPE—INSTALLING—REGULATOR HOUSE—CARE OF REGULATORS—HEATING—REGULATOR BY-PASS—GRINDING VALVES.

Regulators—A gas regulator is practically a reducing valve or set of balanced valves automatically controlling and reducing, by throttling, the pressure of the gas entering an intermediate or low pressure main or line. The regulator is one of the most vital parts in a gas line system, and unless working perfectly will cause a great deal of trouble and loss. Too much attention cannot be paid to the care of the regulator.

As usually constructed, regulators, when working within their range, will maintain a nearly constant pressure in the outlet main. If an attempt is made to reduce the pressure of the gas through more than one hundred pounds, trouble is liable to occur, through freezing.

Fig. 153—HIGH PRESSURE OR REDUCING REGULATOR

The outlet pressure of a regulator is controlled by weights on the lever arm connected with the diaphragm and valve stem.

High Pressure Regulators—A high pressure regulator is constructed with a small diaphragm and a small set of valves to enable it to take care of 500 to 600 pounds safely, and when especially ordered will take care of pressures of 800 to 1000 pounds. The work of a high pressure regulator is to reduce the pressure from a high to an intermediate pressure.

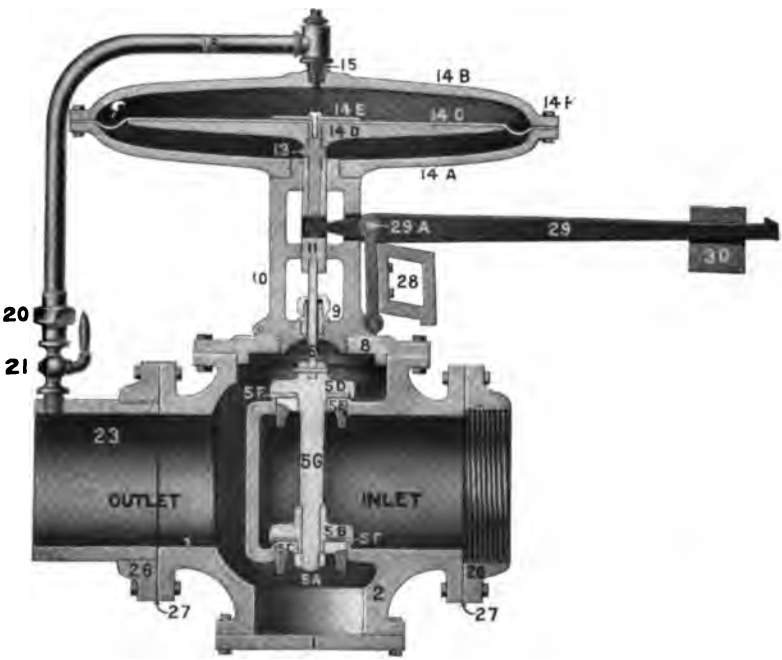


Fig. 154—LOW PRESSURE REGULATOR

Intermediate Pressure Regulators—The work of an intermediate regulator is to reduce the pressure from 50 to 100 pounds down to 15 or 20 pounds, so that the low pressure regulator will control the gas in a more sensitive manner

without too great a reduction. The intermediate pressure regulator is not very commonly used, but when used, it greatly improves the work of both the high and the low pressure regulators. It gives a more sensitive and far safer service.

Low Pressure Regulators—A low pressure regulator takes the gas from an intermediate pressure line and reduces it to a pressure low enough for home consumption, which is from four to six ounces.

A low pressure regulator is built with a large diaphragm and large valves and is very sensitive.

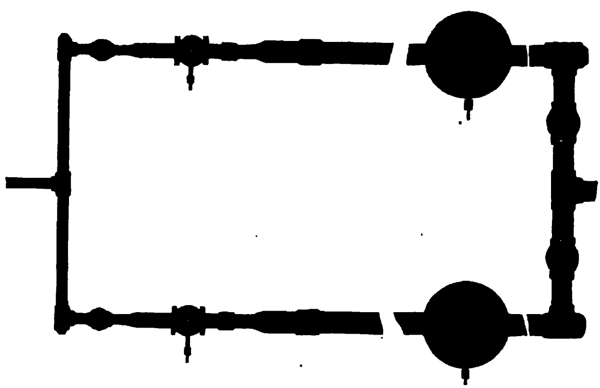


Fig. 156—LOW PRESSURE REGULATOR SETTING

Installing—Small size high and low pressure regulators set on the same line should be about six feet apart. Six-inch and larger sizes should be set twenty feet or more apart, otherwise they are apt to work against one another. It is good policy to use a regulator of larger diameter than the diameter of the high pressure line. Proper gauges should be placed on the high, intermediate and low pressure side. If a by-pass is installed around a high pressure regulator, a gauge on the low or intermediate side should be placed in plain view from the by-pass gate.

It is a very good idea in low pressure systems to place a low pressure recording gauge on the line, and to preserve the charts for reference in case of dispute. Do not set regulators in a pit.

Regulator Diaphragms—Regulator diaphragms should be examined often, and if they show the slightest wear new diaphragms should be substituted. The slightest pin hole in the diaphragm kills the effect of the regulator.

Regulators and Plain End Pipe—When a regulator is to be placed in a plain end pipe line, use two or three joints of screw pipe on the inlet and outlet of the regulator. Where the high pressure line enters the regulator station, the pipe should be well anchored.

Sheet Iron Heater for Gas Line—Fig. 156 shows a sheet iron heater for use on a high pressure line entering a meter or regulator station. The large pipe projecting through the roof carries off the burnt gases and the small pipe runs into the pit to a point near the mixer of the burner in order to slowly supply fresh air. By this method the liability of the mixer receiving gusts of wind is eliminated and a constant fire is assured. A common log burner is used under the pipe.

Care of Regulators—Thaw a regulator with warm water. Do not use oil on a regulator piston rod in winter unless the excess of oil is wiped off, as cold weather chills the oil and causes the piston to stick.

If frost accumulates on the high pressure regulator, increase fire in the heater. If the regulator is frozen solid, care should be used in thawing it out even with warm water, as the regulator is apt to jump and throw high pressure gas into either intermediate or low pressure lines. In the above case it is better to close the gate back of the regulator first, and in the event of the frozen regulator being the only feed-

ing point on a low pressure system, all consumers should be notified that gas will be turned on at a certain hour.

In case regulators are set where the distance between them is so short that they jump, a short piece of pipe, the same size as that used between the two regulators, can be installed at right angles to old line and will act as a reservoir. This, of course, would be a blind end or short joint of pipe capped.

Fig. 156—SHEET IRON HEATER FOR GAS LINE

Heating—In cold weather, or where the reduction in pressure is greater than one hundred pounds, use a gas torch heater back of the small regulator installation. Place it far enough back so that in event of a gate flange gasket blowing out, the escaping gas cannot catch fire from the torch.

Regulator By-Pass—All high and low pressure regulators should be installed with a by-pass. This will enable one to properly clean, inspect, or repair them without interfering with the service ahead of the regulator.

Grinding Valves—When the seats or valves become nicked or worn and cause leakage they can be ground in by hand. Valves should be ground on their own seat, using emery flour and oil.

If a regulator fails to work and the diaphragm is found to be perfect, examine the valves and the pet cock on the breathing pipe running from the top of the diaphragm head to the low pressure side of the regulator. Dirt will cause the valves to stick and the pet cock to become choked.

PART ELEVEN

DISTRIBUTION OF GAS

LOW PRESSURE SYSTEM FRANCHISE—MAPPING—REGULATOR STATION—OIL SAFETY TANKS—SAFETY VALVES—GAUGES—LEAKS—SERVICES—PURIFIERS—RULES AND REGULATIONS FOR HOUSE PIPING.

Description of Low Pressure System—A low pressure system consists of a series or network of gas lines in which the gas is carried at a pressure of a few ounces above atmosphere. This low pressure is maintained in order to lessen the possibility of danger in house piping and burning devices, and at the same time to give adequate service to all consumers regardless of their distance from the regulating station.

It is good policy to use a double system of low pressure mains in city streets where there is a pavement or the possibility of one being laid in the future. In this case the mains should, if possible, be laid between the curb and the sidewalk, one main on each side of the street.

In estimating the possible number of consumers in a city, figure five people to the meter.

Whenever possible, lines should be laid in alleys with services running into the rear of the building. There is less liability of damage suits due to accidents than if the lines are laid in much-traveled streets.

AN ORDINANCE GRANTING TO JONES GAS CO. ITS HEIRS, SUCCESSORS AND ASSIGNS, A GAS LIGHT, HEAT AND POWER FRANCHISE.

Be it enacted by the Board of Commissioners of the City of————:

SECTION 1.--That there is hereby granted to Jones Gas Co. (herein called the Grantee) the right, privilege and franchise to construct, maintain and operate in the present and future streets,

alleys, and public places in the City of ————, and its successors, a system of gas mains, supply pipes and laterals, with all necessary or desirable appurtenances for the purpose of supplying gas to the said City, the inhabitants thereof, and persons and corporations beyond the limits thereof, for light, heat, power and other purposes, and that the rights, privileges, and franchise herein granted shall be, and remain in Grantee, his successors and assigns free from all taxation for a period of twenty-five years from and after the passage of this ordinance.

SECTION 2.—All mains, pipes and laterals shall be so laid as to interfere as little as possible with traffic over the streets and alleys. The location of all mains, pipes and laterals shall be fixed under the supervision of the Street and Alley Committee of the Commission, or the successors of the duties of that committee.

SECTION 3.—Whenever Grantee shall make or cause to be made excavations or so place obstructions in any street, alley or avenue of the City of ———— the public shall be protected from all damage by reason of the existence of such excavations or obstructions by sufficient barriers and lights placed, erected and maintained by said Grantee, and in the event of any injury to any person or property by reason of the construction, operation or maintenance of said gas system, the Grantee shall indemnify and keep harmless the City of ———— from any and all liability, and Grantee shall repair and clean up and restore all streets and alleys disturbed during construction.

SECTION 4.—The rates charged by Grantee for gas sold under this ordinance are hereby fixed as follows, to-wit:

A.—Grantee may charge and collect reasonable minimum monthly bills, which, for domestic customers, shall not exceed One Dollar ($1.00) per month, inclusive of the readiness to serve charge herein provided for.

B.—The net rate for natural gas sold and used for domestic purposes, other than minimum monthly bills, shall never be more than One Dollar ($1.00) per thousand cubic feet, nor less than Fifty Cents (50 cts.) per thousand cubic feet, exclusive of penalties.

C.—The net rate for artificial gas sold and used for domestic purposes other than the minimum monthly bills, shall never be more than Two Dollars ($2.00) per thousand cubic feet, nor less than One and Fifty One-Hundredths Dollars ($1.50) per thousand cubic feet, exclusive of penalties.

D.—Gas made from a mixture of natural and artificial gas may be sold and the rate therefor shall be fixed by the City Commission

as hereinafter provided, and shall be determined by the relative amount of natural and artificial gas contained in said mixture, provided that the rates for mixed gas hereunder shall in no event be lower than the minimum rate named hereinabove for natural and artificial gas, due regard being had for the respective percentage of each.

E.—Grantee may sell natural or artificial gas for industrial and boiler purposes at such rates as he may from time to time elect.

F.—A penalty of Ten Cents (10 cts.) per thousand cubic feet, or fractional part thereof, shall be added to all bills not paid within ten days from the date of rendition.

G.—Natural, artificial or mixed gas furnished hereunder shall be sold at the minimum rate hereinabove provided until a higher rate has been authorized in the manner hereinafter provided.

SECTION 5.—For the purpose of fixing a rate for mixed gas or a rate for natural or artificial gas except the minimum rate as herein provided, the Grantee may from time to time prepare and file with the Board of Commissioners schedules of rates which will enable Grantee to earn a reasonable return upon the fair value of the Plant System and Property, and shall at the same time furnish said Board of Commissioners such information as the Board may require relating to its property in use, and its fair valuation together with its operating expenses, and also the approximate cost of delivering the gas sold to the consumer and the Board of Commissioners shall determine whether said rate is reasonable and either approve or disapprove the same in whole or in part within sixty days from date of filing such schedules. The Board of Commissioners at any time of fixing rates may have under its authority prepared, a schedule of rates, which shall be submitted to Grantee for its consideration, who shall, if they desire, submit objections to the establishment of such rates, and after hearing such objections same shall be approved or disapproved as the Commissioners may determine. The rates for natural, mixed or artificial gas furnished hereunder shall be reasonable, and shall not be lower than will produce a reasonable net return to Grantee, upon the fair valuation of all property, equipments and betterments used by the Grantee for the purpose of supplying gas hereunder to the City of ———— and the inhabitants thereof. The service rendered by the Grantee hereunder shall be first class, adequate and sufficient, insofar as is commercially practicable and consistent with the supply available. If the schedule of charges presented by Grantee shall not be approved by the Board of Commissioners, then said schedule shall, if Grantee

desires, take effect at the expiration of sixty days from the date of filing the same with the Board, provided Grantee shall institute suit in the District Court as hereinafter provided, and file with the Board of Commissioners a satisfactory bond for the protection of its patrons and customers in the event the final adjudication of the matter shall be against the Grantee. If the Grantee be dissatisfied with any decision or order of the Board of Commissioners, the Grantee may file a suit in the District Court of ——— County, ———, with itself as plaintiff, and the City of ——— as defendant, setting forth the action of the Board of Commissioners complained of by it, and the proceedings thereon shall be in accorddance with the laws of the State of ——— now in force, conferring jurisdiction upon the District Court to regulate rates and charges of public utility corporations, except that proceedings herein provided for shall be commenced by the Grantee.

SECTION 6.—In addition to the rates herein allowed to be charged for gas sold, Grantee may charge and collect a "readiness to serve" or "customers charge" from each and every customer in the city limits of the City of ——— in the flat sum of Fifty Cents per month. This charge is agreed and understood to be a charge that each and every customer is to pay, regardless of the amount of gas consumed, or the rate per thousand cubic feet allowed to be charged under this ordinance. Grantee may also charge and collect, for the setting and changing of meters, an amount not to exceed the cost of labor and material used in performing such services, plus ten per cent. additional thereon.

SECTION 7.—Grantee may make and enforce reasonable rules and regulations in the conduct of his business, and may require, before furnishing service, the execution of a contract therefor, and may require each consumer, within the corporate limits of the City of ———, ——— County, ———, to pay Grantee for the installation of all service pipes from the main in the street to and throughout the consumer's premises, and the Grantee shall have the right to contract with each customer with reference to the installation of service pipes and the control of the same from the connection thereof with Grantee's main in the streets to and including the meter located on the consumer's premises.

SECTION 8.—Grantee shall not be required to extend pipes or mains more than fifty feet for any one customer of natural gas.

SECTION 9.—Grantee shall be entitled to require from each and every consumer of gas before gas service is installed, a deposit of twice the amount of an estimated monthly bill, which said deposit

may be retained by Grantee until service is discontinued, and all bills therefor have been paid. And Grantee shall return said deposit to the consumer, together with six per cent. interest thereon from the date of said deposit. Grantee shall be entitled to apply said deposit to any indebtedness owed it by the consumer making the deposit, and when same has been applied to any indebtedness, the gas service can be discontinued until all the indebtedness of the consumer is paid, and a like deposit is made with the Grantee by said consumer.

SECTION 10.—Grantee hereby agrees, in consideration of the granting of this franchise, to pay to the City of ————, annually on or before the 1st day of January each year during the life of this franchise, the sum of One Hundred ($100.00) Dollars in cash.

SECTION 11.—The rights, privileges and franchises granted by this ordinance are not to be considered exclusive, and the City of ———— hereby expressly retains and reserves the right to grant, at any time, like privileges, rights, and franchises, as it may see fit, to any other person or corporation in the City of ————, for the City and other consumers.

SECTION 12.—The Grantee shall file its written acceptance of this franchise within ninety (90) days after its final passage and approval by the Mayor, provided this franchise shall become null and void should there not be constructed by July 1st, 19—, a natural gas pipe line, other than the one now supplying natural gas to the City of ————, through which natural gas is ready for delivery at the city limits on said date.

Peak Load—Every natural gas company is confronted with the serious problem of peak load, and how to obtain an adequate return on the additional investment required. Abnormal peaks of very short duration are characteristic of all natural gas loads. This necessitates a large investment for equipment that is actually used only a very short period out of each year. Even though the peak load equipment is used for a few hours out of each year, the investment must be made to render the service.

Construction of Low Pressure System—Plain end pipe can be used to great advantage in a low pressure system. There should be no dead ends. In cities of 5000 or larger, use a belt line feeding system. This consists merely of feed-

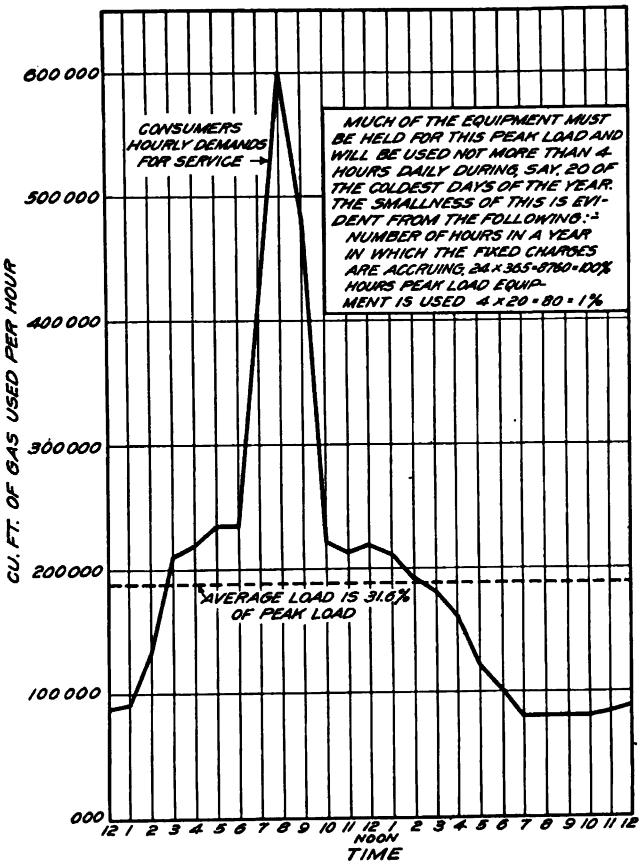


Fig. 157—CHART SHOWING HOURLY PEAK LOAD OF LOW PRESSURE SYSTEM. (*By S. S. Wyer in "Natural Gas Service"*)

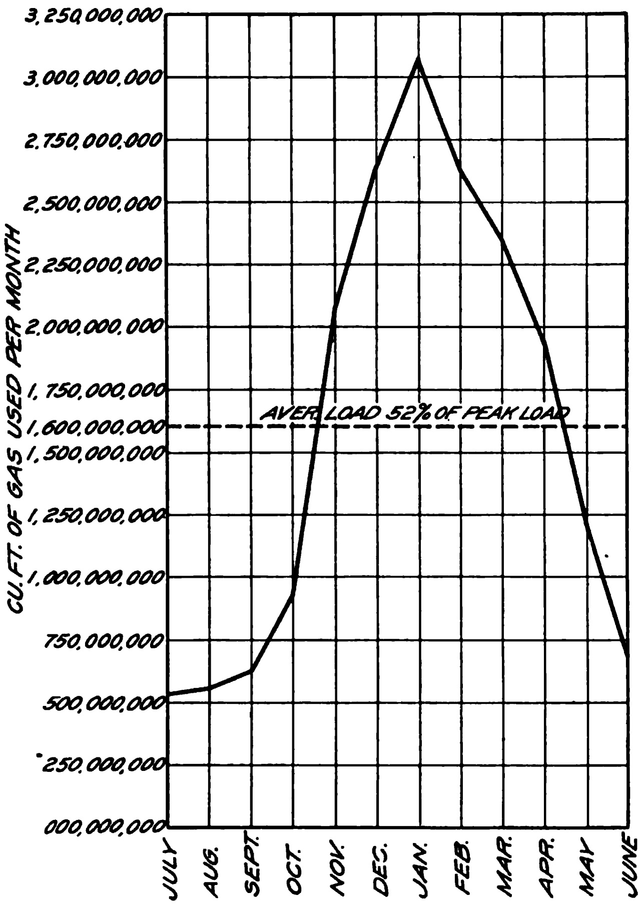


Fig. 158—AVERAGE MONTHLY PEAK LOAD (By S. S. Wyer)

ing the gas from the high pressure line into a belt line at an intermediate pressure, which in turn is connected with different regulator stations where the gas is reduced to a low pressure of generally about four to six ounces. The pressure carried on the belt line should be between fifteen and twenty pounds.

Mapping—When a low pressure system is installed or any new additions made to an old system, it should be properly platted, showing all tees, plugs, expansion joints, bends and other fittings, as well as distances in feet, between streets and from curb to lines.

Size of Mains—Low pressure systems are too frequently installed with pipe of too small a diameter. The larger the main the better will be the service and the lower the pressure necessary to give it.

Low Pressure Main Marker—In laying a new low pressure system or renewing old mains, wherever the work is done at paved street intersections, it is good practice to place a "monument" directly over and connected by chain to the gas main cross or intersection. Top of "monument" should be level with the surface of the pavement and should be lettered to indicate it is the property of the gas company. It will always assist in locating the point of intersection of mains without running a survey or use of blue prints.

Regulating Station or Feeding Points—Regulating stations should be placed at advantageous points in the thickly settled sections of the city or town. The purpose of this is to maintain as nearly as possible, a uniform pressure throughout the whole distribution system under conditions of "heavy pull," or large consumption of gas.

Low Pressure Regulator Station or Building—A well-built regulator house provided with a ventilator and neatly painted is a credit to any gas company.

TABLE No. 75

Table Showing the Approximate Discharge, in Cubic Feet per Hour, of Gas of 0.6 Specific Gravity, in Different Lengths and Diameters of Pipe.

Intake Pressure.............4.0 oz. or 6.9 in. water
Discharge Pressure..........3.7 oz. or 6.4 in. water

(By F. H. Oliphant)

Length in Feet	Diameter of Pipe								
	1 Inch	2 Inch	3 Inch	4 Inch	5 Inch	6 Inch	8 Inch	10 Inch	12 Inch
50	350	2,072	5,775	11,935	21,000	33,250	69,300	122,500	194,600
100	247	1,462	4,075	8,422	14,820	23,465	48,906	86,450	137,332
150	203	1,201	3,349	6,922	12,180	19,285	40,194	71,050	112,868
200	175	1,036	2,887	5,967	10,500	16,625	34,650	61,250	97,300
250	152	899	2,508	5,183	9,120	14,440	30,096	53,200	84,512
300	143	846	2,359	4,876	8,580	13,585	28,311	50,050	79,508
350	136	805	2,244	4,637	8,160	12,920	26,928	47,600	75,616
400	124	734	2,046	4,228	7,440	11,780	24,552	43,400	68,944
450	115	680	1,897	3,921	6,900	10,925	22,770	40,250	63,940
500	110	652	1,815	3,751	6,610	10,450	21,780	38,500	61,160
600	102	603	1,683	3,478	6,120	9,690	20,196	35,700	56,712
700	95	562	1,567	3,239	5,700	9,025	18,810	33,250	52,820
800	88	520	1,452	3,000	5,280	8,360	17,424	30,800	48,928
900	83	491	1,369	2,830	4,980	7,885	16,434	29,050	46,148
1000	76	449	1,254	2,591	4,560	7,220	15,048	26,600	42,256
1100	73	432	1,204	2,489	4,380	6,935	14,454	25,550	40,588
1200	71	420	1,171	2,421	4,260	6,745	14,058	24,850	39,476
1300	68	402	1,122	2,318	4,080	6,460	13,464	23,800	37,808
1400	66	390	1,089	2,250	3,960	6,270	13,068	23,100	36,696
1500	64	378	1,056	2,182	3,840	6,080	12,672	22,672	35,584
1600	62	367	1,023	2,114	3,720	5,890	12,276	21,700	34,472
1800	58	343	957	1,977	3,480	5,510	11,484	20,300	32,248
2000	55	325	907	1,875	3,300	5,225	10,890	19,250	30,580
2500	50	296	825	1,705	3,000	4,750	9,900	17,500	27,800
3000	47	278	775	1,602	2,820	4,465	9,306	16,450	26,132
3500	42	248	693	1,432	2,520	3,990	8,316	14,700	23,352
4000	40	236	660	1,364	2,400	3,800	7,920	14,000	22,240
4500	37	219	610	1,261	2,220	3,515	7,326	12,950	20,572
5280	34	201	561	1,159	2,040	3,230	6,732	11,900	18,904

Install a low pressure recording gauge, with either twenty-four hour or seven-day clock and chart on the low side of the regulator, and require the charts to be turned into the main office as soon as taken from the gauge. This will not only show the continuous pressure on the mains but will also act as a check on the regulator inspectors or caretakers. In summer, when the consumption is low, the tendency of a caretaker is to neglect the inspection of regulators.

Oil Safety Tank—An oil safety tank consists of a sheet-iron drum or cylinder of reasonable size with pipe flange connections on the top. The inlet to tank should be of the same size pipe as the low pressure main and should run down through the top of the tank to within six inches of the bottom. The outlet should consist of a short piece of pipe the same size as the inlet, to act as an escape for the gas, and where the tank is placed in the interior of a building the outlet should be continued to the outside. A sufficient quantity of oil is placed in the tank, to seal the end of the inlet pipe, the depth depending upon the pressure at which it is desired to have it blow. If the pressure exceeds this value it will overcome the head produced by the seal and the gas will escape through the tank and relieve the pressure on the main. As soon as the pressure drops back to its normal value the oil seal automatically closes the pipe again. A salt-water brine can be used in stead of oil.

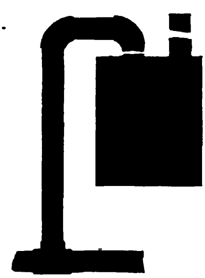


Fig. 159
LOW PRESSURE OIL SAFETY TANK

Turning Gas into New Low Pressure System—After turning gas into a new low pressure system and before opening any service cocks, the air should be let out slowly along various points of the line. After the gas has been first turned into the service, the air should be let out of the service

through some stove or other opening by an inspector or competent employee of the gas company.

Fig. 160—TESTING A SECTION OF LOW PRESSURE SYSTEM WITH A SMALL AIR COMPRESSOR AND GAS ENGINE FOR POWER INSTALLED ON A WAGON

Testing Low Pressure Systems—In constructing a low pressure system it should be tested after each day's work with at least thirty pounds pressure of air or gas but not with a combination of the two. When using air pressure an air pump (steam driven) can be used, and where the system is large the air can be pumped in over night and the inspection made in the morning.

It is good policy to make a few service taps under pressure while testing. This will assist in cleaning the line as well as closing small leaks.

LINE LOSS OR LEAKAGE IN DISTRIBUTING PLANTS.

The chart shown in Fig. 162 is a very good illustration of the percentage of leakage to the amount sold through domestic meters in a southern city, when the continuous meter reading system is used. The greatest line loss appears in the fall of the year and the least in early spring, which in one

month showed more sold than purchased. This was entirely due to the continuous meter reading system.

To further illustrate, the large meters measuring the gas sold to the distributing company were read at the end of the month and showed the exact amount of the gas delivered during the full calendar month. The continuous meter reading system was employed—some of the domestic meters

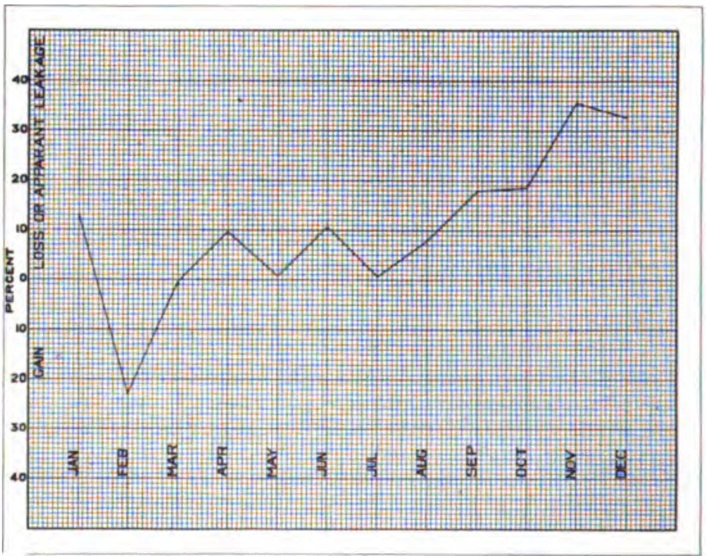


Fig. 162—CHART SHOWING LINE LOSS WHERE METERS ARE READ CONTINUALLY THROUGHOUT THE YEAR

were read each day (excepting Sundays and holidays) during the month. Consequently only the domestic meters read the last day of the month would show the gas consumed during the calendar month, while those read early in the month would show the major part of the gas consumed in the previous month. Yet in both instances the bills would necessarily have to be considered as bills in the month in question.

If November was a fairly warm month and December a cold month, for any domestic meters read early in December the bills would be light on account of the major portion of the gas-consuming period reaching back into November. All domestic meter bills for December would be totaled and compared with the readings of the large meters at edge of the city, and the result in this case would be a heavy line loss or leakage for December.

Fig. 163—SERVICE LINE DESTROYED BY CHEMICALS IN THE SOIL

To sum it up, when a cold month follows a warm month the former will show a large line loss and *vice versa.*

The true way to determine the exact line loss or leakage is to figure it over a period of one year or more in which case the average percentage gives a more accurate idea of same.

The difficulty in deriving a true line loss or leakage percentage figures is more then offset by the many advantages found in the continuous meter reading system.

Leaks—While leaks can be closed around collars by caulking, it is better to use collar leak clamps. Collar leak clamps take better hold and need less tightening after being put in use if the end of the collar has a flat face or surface.

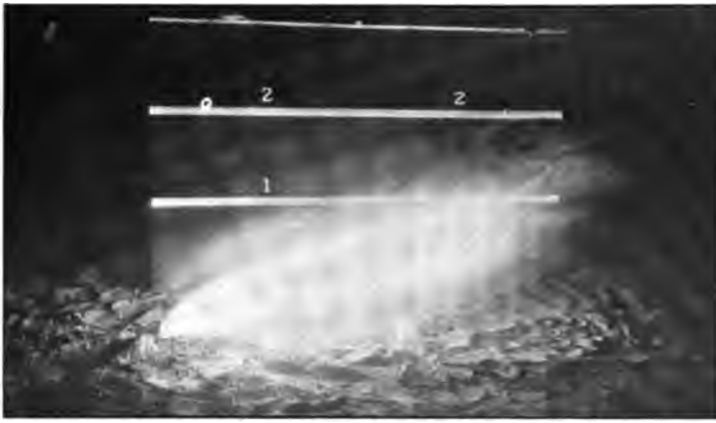


Fig. 164—ONE METHOD TO MEASURE A SMALL LEAK IN A GAS LINE. FIGURES ON CURTAIN INDICATE HEIGHT IN FEET

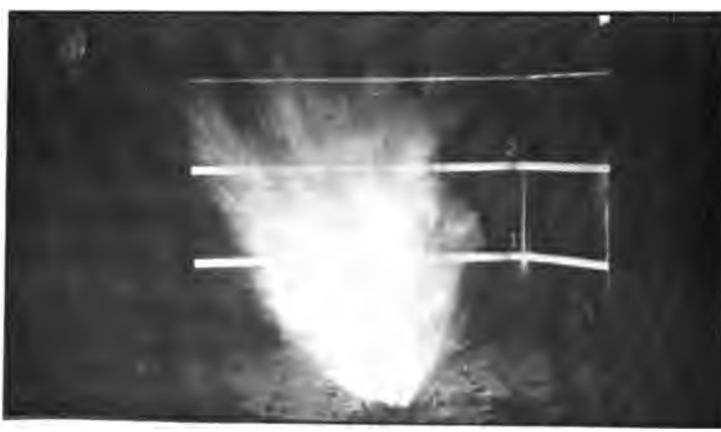


Fig. 165—SAME AS Fig. 164

ELECTROLYTIC MITIGATING SYSTEM.

By ALBERT F. GANZ, Electrical Engineer.

"The insulated radial track return feeder system aims to relieve the tracks of current by insulated conductors and thus aims to prevent currents from escaping into the ground. With a properly laid out track return feeder system, together with properly bonded tracks, it is possible and practicable to minimize stray currents through the ground and therefore stray currents on underground piping to any desired minimum value, and such currents may be made so small as to be negligible. This system removes the cause of the trouble, in that it relieves underground piping systems of dangerous stray currents. It removes danger from sparking as well as dangers from electrolysis, and does not require changes to be made in the railway system when changes in the underground piping system are made. In fact it leaves underground piping systems separate and independent of railway systems, which is certainly a safer and more preferable condition than to deliberately make such piping systems a part of the railway return circuit and a carrier of return railway current.

"With the tracks of two systems connected together, not only at cross overs, but also where necessary by cross bonding cables, these tracks become available for the joint use of the return currents from both systems with the result of greatly reducing the potential gradient in these tracks with corresponding reduction in stray currents through ground.

"It is the unquestionable duty of those who distribute electric currents to so control them as to prevent such currents from damaging others. Good engineering practice of to-day makes it possible and practicable for single trolley electric railways to provide a return circuit which will prevent escape of large and serious stray electric currents into the ground. Where such large and serious stray electric currents are allowed to escape they become a source

of danger to the lives and property of the public and to the property of other utilities of the municipality. The escape of such currents should, in my opinion, be controlled through the enactment and enforcement of a suitable ordinance based on the police powers of the municipality, exactly as other nuisances which endanger the public are now controlled."

In connection with Mr. Ganz's article, the writer herewith cites an incident that happened in the city of Buffalo which fully bears out the statement that stray electric currents on gas and water mains are not only destructive to the main but often cause explosions at distant points from the main. In one of the fire engine buildings situated in the center of the city a tin gas meter was hung from the wall near the ceiling, in close proximity to a water pipe connected with the city water service. At the time of the accident several firemen then on duty were seated within plain view of the meter. Apparently, without any known cause, a flash occurred about the meter, melting same and instantly starting a fire, which of course on account of its quick discovery was easily extinguished without any great damage. If this had happened under most any other circumstances it very likely would have caused a disastrous fire.

While this case created considerable wonderment it was soon solved and the cause attributed to stray currents jumping from either the water pipe to the meter or *vice versa*, melting the solder on the meter.

With reference to the foregoing, it will be noted that on page 513, under "Installing Domestic Meters," the author states: "In cities having street car service do not set the meter near any water or artificial gas pipes."

ELECTROLYSIS REMEDIAL MEASURES.

"The following form of ordinance has been prepared for the purpose of providing regulations which will relieve dangerous conditions due to currents escaping from electrical distribution systems, which currents are a constant source of damage and create a serious

hazard to the public and to the property of public utilities. The provisions of the ordinance are based upon the present state of the art as determined by extended studies and practical experiences in this country and abroad. Considering the dangers to be guarded against and the magnitude of property interests to be protected, the provisions of this ordinance are, in our opinion, necessary and reasonable and its enforcement will not impose an undue burden upon those affected by its terms.

ALBERT F. GANZ, Consulting Electrical Engineer, Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J.

HOWARD S. WARREN, Engineer, American Telephone and Telegraph Company, New York, N. Y.

SAMUEL S. WYER, Consulting Engineer, Columbus, Ohio.

New York, N. Y., April 11, 1913.

ORDINANCE No.......

To Protect the Lives and Property of Persons From Danger Due to Stray Electric Currents Through Ground.

WHEREAS, electric currents escaping into the ground from electrical distribution systems are a constant source of danger to the lives and property of the public and a constant source of injury to underground water-pipes, gas-pipes, cable-sheaths, and other underground metallic structures; and,

WHEREAS, it is deemed necessary for the general safety of the public and the necessary conduct of the public service to restrict and limit the escape of electric currents from electrical distribution systems:

BE IT ORDAINED by the Council of the......................... of..., State of Ohio:

SECTION 1.—It shall be unlawful for any person, firm or corporation to construct, operate or maintain within the limits of the municipality of....................any system of circuits used by such person, firm or corporation, for carrying electric currents, which system at any one time conveys from any one point to any other point more than one (1) kilowatt of electric power, unless such current-carrying electric circuits are so constructed, operated and maintained as to fulfill the requirements hereinafter set forth.

SECTION 2.—All metallic conductors forming parts of such current-carrying electric circuits shall be insulated from the ground wherever it is practical so to insulate them; or if in the case of any particular metallic conductor such insulation shall be impracticable,

then and in such case the said particular metallic conductor which can not be insulated shall be so constructed and maintained as to afford as high a resistance to ground as practicable.

SECTION 3.—Whenever any such metallic conductors forming parts of such current-carrying electric circuits are not insulated from the ground, such circuits shall be designed, installed, operated and maintained, so that the average potential difference during any ten (10) consecutive minutes between any two (2) points one thousand (1,000) feet apart on said metallic conductors will not exceed one (1) volt, and further, so that the average potential difference during any ten (10) consecutive minutes, between any two (2) points more than one thousand (1,000) feet apart within the limits of............ on such metallic conductors, will not exceed seven (7) volts.

SECTION 4.—To aid in determining whether or not the requirements of this ordinance are being complied with, every person, firm or corporation referred to in Section One hereof, constructing, operating or maintaining metallic conductors not insulated from the ground, forming parts of such current-carrying electric circuits, shall provide and maintain insulated potential wires extending from some common point located within the limits of................. to an adequate number of points on said metallic conductors, such points to be designated from time to time by the authorized representative of the municipality, and such person, firm or corporation shall also provide an adequate number of volt meters so arranged with reference to the said insulated potential wires that the potential differences between the said points on said metallic conductors may be readily and accurately measured; and the potential differences between some one of said points and each other of the said points, as determined by readings of said voltmeters taken at least once every thirty (30) seconds during ten (10) consecutive minutes, shall be measured and recorded, said readings to be taken at least once every week, on a business day, during the one (1) hour of maximum difference of potential. In lieu of such readings there may be substituted the continuous records from an adequate number of recording voltmeters installed as aforesaid. The authorized representative of the municipality and any other interested person shall have access to such potential wires, voltmeters and records, and shall have the right to be present and witness such measurements, and shall further have the right to make such additional measurements as he may consider necessary or desirable.

SECTION 5.—Any person, firm or corporation violating any of the provisions of this ordinance shall, upon conviction, be fined

not more than Three Hundred Dollars ($300.00) for each offense, and each day's operation of such system of current-carrying electric circuits contrary to this ordinance shall constitute a separate and distinct offense.

SECTION 6.—This ordinance shall take effect and be in force from and after four (4) months from its passage and legal publication."

The foregoing ordinance has been adopted by several cities in Ohio, and in one instance validated in court.

Fire Alarm in Gas Office—Some gas companies, especially in the South where wood construction predominates and cellars are lacking, have installed a fire alarm (same as at a fire engine house) in the superintendent's or other office of the company and have a man on duty both day and night with motor cycle and tools, to answer all alarms. In case of an explosion it permits the gas company to obtain first hand information.

Gauge Alarm—When it is desired to make a gauge alarm to be used either on a high pressure line entering a low pressure feeding station or on an intermediate or belt line pressure, the following method can be employed: use an ordinary spring gauge and drill a $\frac{1}{8}$-inch hole about 1 inch from the outer circumference of the glass dial. Remove the insulation from the end of a wire and insert same into the hole in the glass dial to within $\frac{1}{16}$-inch of the graduated gauge dial, taking care, however, that it does not touch the latter. Attach another wire to the pipe leading to the gauge. The two wires can be strung any distance to a common electric bell and dry batteries. The wire in the glass dial of the gauge should be turned to a position opposite the pressure on the dial at which it is desired that the bell should ring. When the pressure drops to this point, the gauge hand will make a contact with the wire, thereby causing the bell to ring.

Stealing Gas—The consumer who tampers with a gas meter, or uses a by-pass to obtain gas without registration,

commits a crime the same as though he walked into the gas office and stole money from the cash drawer.

Many companies, especially those employing the continuous meter reading system, offer a regular scale of rewards to their meter readers and employees for detecting by-passes, tampered meters (diaphragm punctured, or otherwise injured to cause meter to run slow) tipping meters, leaks at meters, leaks in street, etc.

Some companies are paying the following rewards:

By-pass (whole house)	$2.00
Straight connection	1.00
Line off service	.75
Leak in meter case	.10
Leak at dial	.05
Meter binding	.10
Not registering on low fire	.15
Not registering	.50
Leak in service curb box	.10
Leak in main line	.25

Some meter readers reading meters continually use the extra three or four days a month not employed in reading, to scout about their route and find gas steals or leaks. When this method is employed the salary paid is usually under the customary salary paid for reading meters only. The rewards bring the amount of money earned to more than the regular salary.

Employees soon become exceptionally keen in detecting the odor of escaping gas or in finding gas steals.

A similar method is employed with bookkeepers in detecting gas steals. The bookkeeper keeps continual watch on the amount of each month's gas bill. If he finds it particularly small he reports it and if it proves to be a case of gas stealing he is rewarded accordingly.

Suggestions to Gas Companies and Employees—Never forget the danger and results of a gas explosion. One careless act may cost the company a $10,000 law suit. Polite-

ness and courtesy in dealing with consumers will overcome the natural suspicion the public holds toward the gas company. Practically all suspicion of gas company's methods starts with the employees or representatives.

Remember in talking to a consumer that you—at one time—knew as little about natural gas as the consumer you are talking to.

A good complaint man is the most valuable of employees of a gas company.

Never leave a large leak unrepaired or unguarded.

Do not depend upon sense of smell, hearing, rain, or flies to determine if your low pressure mains are gas tight. None of the foregoing will tell you accurately or conclusively. Except to ditch down to the main—the bar test is the only accurate method of determining leaks in gas mains.

It is good practice, in cities, to take samples of gas from sewer manholes and have the gas analyzed. The results will show the percentage of natural gas to air or sewer gas. Gas will travel through an entire sewer system. If any natural gas is shown in the analysis, find the manhole showing the greatest percentage of natural gas, then look for leaky mains in that vicinity. In one city the writer found a gas engine working with gas sucked from a sewer. In this instance the leak, which had been caused by electrolysis, was located one block away from the engine. After the leak had been repaired the gas engine was compelled to receive its gas through a gas meter.

Wireless Pipe Locator—This instrument consists of a special form of vibrator and an induction coil with six batteries, together with detector coil and receiver for tracing the circuit. The advantage of this outfit is that it enables the operator to locate lost gas services, mains or water pipes under the ground between two points.

In operating the locator it is necessary to attach one wire to the main in the street or curb box and the other wire

to the gas service in the building or on the main at the other known point. After attaching the wires at these two points the operator can trace the pipe intervening between the two points by holding the receiver to the ear and following the noise or tone.

In noisy streets or where the line lays deep it is necessary to use from ten to twelve dry cells.

It will not locate stub lines, but only a pipe line between two points where wires can be properly attached.

Where gas lines in a house are connected with a hot water heater, disconnect the gas meter and make connection on the inlet connection of the service line. Otherwise part of the current is liable to follow the water lines, making it hard to detect the tone.

Purifiers for Natural Gas for Domestic Service—Where natural gas contains a high percentage of sulphur gas, the excess can be removed by using a small tank holding about a bushel of shavings and oxide of iron and provided with a cover flange that will permit the removal and changing of the shavings and oxide of iron at least once a year. It is practically the same process in a small way as is practiced in the producer gas plants.

This tank should be installed on the inlet side of the domestic meter. As there are only a few instances in the country where this purifying of natural gas is necessary, the gas companies are obliged to have their own tanks specially built.

The tank might be described as being about the size of a dish pan with a cover, and with the inlet and outlet on opposite sides. The outlet and inlet connections are generally for 1-inch or $1\frac{1}{4}$-inch pipe.

Safety or Pop Valves—Where metal safety valves are smaller in diameter than the size of the main, they will not take care of a sudden rise of pressure in a low pressure main.

In order to be effective the safety valve should be of the same diameter as the gas main.

Oil tanks can be used only on low pressure system. For high or intermediate pressure, use a specially made safety valve. This style of valve is generally used on intermediate or belt line pressure.

Low Pressure Gauges—The mercury gauge which is most commonly used on low pressure systems consists of a cast-iron body, and a glass tube for the mercury column, with a scale (in pounds) back of the glass tube. Each space is divided into sixteen parts or ounces, each large division representing one pound. This gauge is not read in tenths of one inch but in ounces and pounds, and is made in 3, 5, 7, 10, 15, 20, and 25 lb. sizes.

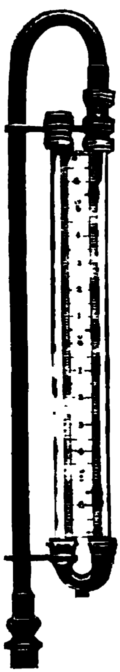


Fig. 166
SIPHON OR U GAUGE FOR LOW PRESSURE

Siphon or "U" Gauges—These are the most convenient low pressure gauges in use, being portable and simply screwed to the piping wherever it is desired to take the pressure.

They consist of a U-shaped tube made of small sized glass tubing bent to shape in sizes from 4-inch to 10-inch; and, in larger sizes, of two straight glass tubes connected at the bottom by a brass bend. Between the two sides or legs of this tube is set a scale graduated in inches and tenths, or pounds and ounces, as desired. A bent brass tube, or goose-neck, is connected to the "U" tube at the top and runs down the side to the gas connection. A filling screw is provided for the water or mercury and a vent where the goose-neck is connected to the "U" tube to relieve the gas pressure on the inlet side after shutting off the gas at the pipe.

When used the gauge is filled with water or mercury to the center of the scale, which is

zero. The gauge is connected to the gas supply and the pressure turned on. The liquid will fall below zero on the inlet side of the "U" tube and rise on the opposite side the same distance. The distance between the two levels of the liquid as shown by the scale will give the amount of pressure in inches and tenths or in pounds and ounces, according to the graduation.

Fig. 167—MERCURY PRESSURE GAUGE

While the gauge is in use the downward motion of the liquid in one column, due to the pressure of the gas, should equal the rise of liquid in the opposite column. In case the water, after being set at zero, should not drop on the pressure side as much as it rises on the other side, it is an indication that the glass tubes are not of equal diameter, and both columns must be read, their sum being the true pressure.

Water is generally used in siphon gauges in testing domestic meters and measuring small gas wells. It is also used in testing large capacity meters in the field.

SERVICES AND HOUSE PIPING

Fig. 168—TAPPING MACHINE

Tapping for Services—Tapping machines for making taps for services in low pressure mains are found very practical. By using the cup in making the tap, considerable gas can be saved that otherwise would be lost.

Care should be used to note that the machine is absolutely tight on the main before starting to drill.

TABLE No. 76—PROPER SIZE TAP DRILLS TO BE USED FOR THE DIFFERENT SIZED PIPES.

Nominal Size Inch	Tap Drill Inch	Nominal Size Inch	Tap Drill Inch
1/8	11/32	1 1/2	1 3/4
1/4	7/16	2	2 1/4
3/8	9/16	2 1/2	2 11/16
1/2	11/16	3	3 5/16
3/4	15/16	3 1/2	3 13/16
1	1 3/16	4	4 5/16
1 1/4	1 1/2		

Services—In tapping a low pressure gas main for domestic use, connections should be made with two street ells. Do not use smaller than 1¼-inch ell or service. The larger the pipe the better the service. Stop cocks should be placed on the service near the curb on the walk side and a curb box placed over same. Prior to placing a stop cock in the line, the core of same should be oiled so that it can be easily turned by the long wrench purposely made for use in curb boxes.

Expansion sleeves can be used to good advantage. If the street service and curb box are installed first and the service line, laid by a plumber or gas fitter later should be slightly out of line, the sleeve will take care of the discrepancy and make a tight joint. Leave a 10-inch or 12-inch nipple on outlet of curb cock to be used for sleeve connection. Nipple should be capped or plugged on outlet side till sleeve and service are laid.

Steel Pipe—Do not use small-sized steel pipe in house piping where it is desired to make any bends in the pipe.

Testing House Piping—After piping a residence for natural gas and before turning the gas into the piping, an air test should be made with fifteen pounds pressure on the house piping prior to connecting house piping to meter.

This test should be made in the presence of a representative of the gas company before a permit is issued to the consumer to use gas. The method of detecting leaks under air pressure is either by using soap suds applied to the joints or using ether in the air that is pumped into the line.

In making this test, the test gauge should be placed in a vertical position.

Gas Proving Pump and Gauge—Fig. 169 shows a gas proving pump and gauge used for making air tests in house piping. A common spring gauge can be used instead of mercury column. The pump is equipped with cup for admitting

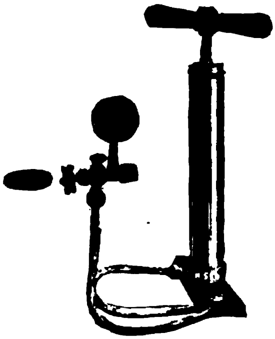


Fig. 169—GAS PROVING PUMP AND GAUGE

ether into piping, in which case leaks can be detected from the smell of leaking air and ether.

Rules and Regulations for Gas Fitting—For a complete set of rules and regulations for house piping, setting up domestic meters, etc., the following suggestions are submitted. While various companies publish different rules, an effort has been made to select such rules and regulations as are most generally used.

RULE 1—In piping new houses the gas company will decide where gas meter shall be located and the fitter shall extend the riser to terminate within 18 inches of the proposed location of the meter and to the right of same.

RULE 2—Provision must be made to place the meter on a solid support where it can be conveniently read and protected from the weather. Meters shall not be located under side-walks, or show-windows, near furnaces or ovens; locked in compartments, or placed in other positions where they will be inaccessible to adjust. Under no conditions shall plumbers, fitters or other parties disconnect any meter, connect to, or disturb piping on inlet side of meter after once set.

RULE 3—To accommodate different tenants the company will set as many meters as there are separate consumers in a given building, connecting the meters to one service pipe, providing the service is large enough to provide an ample supply, and that the risers or pipes leading to the different tenants are extended to within 18 inches of the proposed locations of the meters.

RULE 4—Risers must not be scattered but must be dropped together in alignment to the room where meters are

set. They must be kept at least three inches apart and extended not less than twenty inches from the floor.

RULE 5—Elbows and not tees shall be used on all meter inlet connections. All connections or disconnections of meter for any purpose will be made by employees of company only.

RULE 6—All gas pipes must be graded from meter to risers, free from traps or sags and properly supported with screws and gas pipe hooks or hangers. When it is impossible to prevent a trapped gas pipe, a suitable drip shall be provided, consisting of a nipple and cap located in an accessible place.

RULE 7—Rubber hose connections or fittings arranged for rubber hose connections for gas heaters or similar appliances will not be allowed.

RULE 8—Cement shall not be used or caulking done to repair faulty fitting work, and all imperfect fittings must be replaced.

RULE 9—In no case shall valves or unions be placed between ceiling and floor or in an inaccessible place so that the stuffing box of the valves cannot be repacked or union gasket replaced.

RULE 10—Where globe valves are used on fire connections, the stems must be packed with asbestos packing. "Soft seat" valves must not be used.

RULE 11—In running a line through a flue great care must be taken to see that pipe and fittings are free from defect.

RULE 12—Lead pipes must not be used under any circumstances.

RULE 13—Use as few elbows as possible. Elbows not absolutely necessary will be condemned. When impossible to get through an obstruction such as a beam, offset the pipe rather than use elbows.

RULE 14—Cast iron fittings will not be permitted.

RULE 15—Air mixers must not be placed in air-tight ash boxes, but where a free flow of air can reach them at all times. Use adjustable mixers.

RULE 16—The burr left on inside of gas pipes must in every case be reamed out.

RULE 17—All outlets or risers where fixtures are not placed must be left securely capped.

RULE 18—All drops and openings for lights must project at least 1 inch beyond plaster of wall or ceiling, and must be securely fastened to joists or studding or to notched or cross pieces fastened to joists, or upright studding.

RULE 19—Unions or bushings shall not be used excepting to connect stoves or fires.

RULE 20—No more than one elbow will be allowed between burner and mixer.

RULE 21—Burners must have threaded connections. "Slip joints" will not be allowed.

RULE 22—In re-modeling or extending old gas piping, connections must be made where sizes can be maintained. If this cannot be done, a new line must be run to meter.

RULE 23—All gas piping must be tested with air pressure on a mercury or spring gauge showing ten pounds, which shall be maintained for fifteen minutes without falling. Gas will be turned on by an authorized agent of the company only, after such test has been properly made and report of same filed with the gas company. If meter stop is closed, do not open under any circumstances. Application must be made to the company for gas to be turned on. Fire tests will not be allowed under any circumstances on inside work.

RULE 24—Where pipe runs through a stone or brick wall opening around the pipe must be cemented.

RULE 25—Place a damper in all stove-pipe and chimney throats.

The table following shall govern the greatest length of pipe of the various sizes specified to be used for fuel and illuminating purposes:

TABLE No. 77

For 1 Stove, 1-inch Pipe.
For 2 Stoves, 1-inch Pipe to first, ¾-inch to second.
For 3 Stoves, 1-inch Pipe to first and second, ¾-inch to third.
For 4 Stoves, 1¼-inch Pipe to first and second, 1-inch to third, ¾-inch to fourth.

Gas Lighting

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet	Greatest Number of Burners
⅜	15	1
⅜	10	4
½	25	6
¾	40	15
1	70	35
1¼	100	60
1½	150	100
2	200	200

¼-inch pipe will in no case be allowed.

Gas Ranges

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
¾	40
1	70

Automatic Water Heaters

Heater No.	Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
3	1	70
4	1¼	100
6	1½	100
8	2	125

Instantaneous Water Heaters

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet
¾	40
1	70
1½	100

Fires

Size of Pipe Inches	Greatest Length Allowed Inside Building Feet	Number of Fires
½	10	1
¾	30	1
1	100	1
1¼	350	1
¾	20	2
1¼	60	2
1¼	160	2
1	40	3
1¼	120	3
1	20	4
1¼	90	4
1¼	70	5
1½	125	5
1¼	40	6
1½	90	6
1½	30	7
1½	75	7
1¼	15	8
1½	50	8
1½	40	9
1½	30	10

Hot Air Furnaces

For hot air furnaces, boilers, etc., using burners having two or three mixers, use 1¼-inch pipe.

TABLE No. 78

Capacities of Thin Orifices in Cubic Feet per Hour.

Diameter of Orifice Inches	Pressure (Inches of Water)					
	1	1.7	3.4	5.2	6.9	8.6
	Capacity per Hour (in Cubic Feet)					
$\frac{5}{64}$	6.3	8.2	12.5	15.9	18.4	20.
$\frac{3}{32}$	10.3	13.6	19.4	23.9	27.3	30.7
$\frac{7}{64}$	13.3	18.4	26.5	32.1	37.4	41.1
⅛	20.4	26.5	37.1	45.9	53.2	57.8
$\frac{5}{32}$	25.4	34.7	49.8	61.6	72.	80.3
$\frac{3}{16}$	40.2	52.9	79.5	95.7	111.	124.
¼	61.	82.5	119.	147.	168.	191.
⅜	131.	178.	253.	300.	352.	400.
$\frac{7}{16}$	173.	229.	333.	409.	467.	529.
½	222.	294.	418.	514.	600.	654.

Note—The above table was made from actual tests.

Specific Gravity of gas 0.64.
Atmospheric pressure 14.4 pounds.
Measurement basis 4 ounce.

PART TWELVE

ACETYLENE WELDING*

Description of Gases

"**Oxygen**—It has no odor and is invisible. It is usually supplied in steel cylinders or tanks. The standard cylinders hold 200 cu. ft. of oxygen. The oxygen is pumped into these cylinders at 1,800 lb. pressure. The amount of oxygen in a cylinder can be determined by looking at the high pressure gauge of the regulator. In general, for every 9 lb. pressure below the filling pressure of 1,800 lb., there will be 1 cu. ft. less of oxygen in the cylinder. A mixture of oxygen and gas, being explosive, should be avoided in the presence of a flame. Oxygen also will combine with grease, oil, or other inflammable materials with explosive violence. The oxygen regulator and the valve of the oxygen cylinder should therefore not be greased or oiled at any time. Care must be taken that the gauges on the regulator have no oil or grease on them. An oxygen cylinder, when filled, should be handled carefully, because there is such a high pressure within it. Do not knock it over or drop it. When the cylinder is not in service, the valve should be protected by means of a cap, which comes with it. Before attaching a regulator to the cylinder valve, always first "crack" the valve (open the valve slightly) both to clean out the valve and to see that it is operating properly.

Acetylene—Acetylene is the gas that burns in the oxy-acetylene flame. When it is burned alone, without any previous mixture of oxygen, it produces a yellowish, smoky flame. When mixed with oxygen, it produces a bluish white flame. It is an invisible gas, but has a distinct odor. Acetylene is made by dropping calcium carbide into water. The acetylene bubbles up through the water, leaving a white sludge of slaked lime at the bottom of the vessel.

* Considerable data in this chapter is taken from the "American Gas Works Practice" by George Wehrle, published by the Gas Age.

It is not practicable to compress acetylene at a high pressure into an empty tank, as is done with oxygen. This is because acetylene at a high pressure may explode. For this reason a different style of tank is used. Inside the tank is placed a material that is porous. This material is soaked in liquid acetone. Acetylene will be dissolved by this liquid just as sugar is dissolved in water. When acetylene is pumped into a tank of this kind, it is safe. It is never pumped up to a pressure above 250 lb. The tank of acetylene usually contains 300 cu. ft. of gas.

No blowpipe that will empty it in less than 7 hours should be used on any acetylene tank. If the tank is emptied in a shorter time than this, the liquid will be drawn out of the tank. Do not drop or jar an acetylene cylinder. Handle it carefully. Always keep an acetylene cylinder in as cool a place as possible. Do not stand it near a fire. If possible, it should be kept out of the hot sun.

Before connecting an acetylene regulator to a tank, be sure that the cylinder valve is operating properly and that there is no leakage around the nut of the stem. Because acetylene is inflammable, all leaks in the cylinder valve, hose and connections should be avoided. If there is a cap supplied for the tank valve, always see that this is in place before moving the cylinder. Do not transfer acetylene from the cylinder to an empty tank. Avoid large volumes of acetylene under pressure. Acetylene will act on pure copper so that it will produce an explosive compound. Because of this, never use copper in the acetylene equipment. Brass or bronze, however, can be safely used. Do not attempt to locate a leak in the acetylene connections with an open flame. To locate a leak use soap and water with a brush. When the leak is located, bubbles will appear.

Because acetylene is not compressed in an empty tank like oxygen, but is dissolved in a liquid, it is not possible to determine the amount of acetylene being used by the

valve for a few seconds. Then open this valve fully and relight the blowpipe. If the backfire continues, close both the acetylene and oxygen valves, then relight the blowpipe. If the blowpipe becomes heated, it may be cooled by plunging it into a bucket of water. When this is done, be sure that the acetylene has been shut off and a small quantity of oxygen is passing through the blowpipe.

Welding Heads—There are 10 sizes of welding heads supplied with a blowpipe. Each of these heads gives a certain size flame adapted to a given thickness of metal. The acetylene pressure for all the heads is the same—namely, 1 lb. The oxygen pressure varies, ranging from 9 to 30 lb., according to the size of the head.

Oxy-Acetylene Flame—When the oxy-acetylene flame has just the right proportion of each gas, it is called neutral. This is shown by a clearly defined central cone, bright bluish green in color, surrounded by a bushy, weak flame, purplish yellow in color. When too much oxygen is used, this central cone or jet becomes bluer in color and loses the greenish tinge; it is not so clearly defined. When too much acetylene is used, the jet becomes bluish white and is streaky. The neutral flame should always be used. The operator should test his flame from time to time as he is welding. This is done by turning on a slight excess of acetylene, by means of the acetylene valve, and then trimming it down so that a neutral flame is produced.

Preparation of Welds—The success of oxy-acetylene welding depends, to a very great extent, upon the proper preparation of the parts to be welded. While the preparation of a weld depends very much upon the particular location and condition of the parts to be welded, there are nevertheless certain general rules that must be followed. The preparation should be given as much consideration by the welder as are the proper selection of welding rods, fluxes and

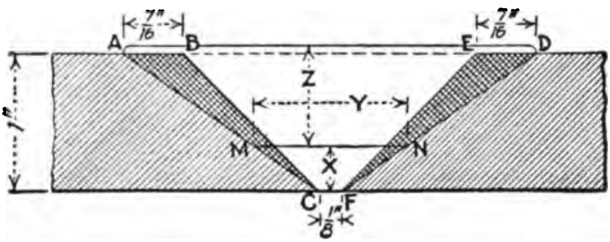


Fig. 171—PIPE BEVEL AND SECTION MELTED

size of blowpipe head. The weld that is not prepared properly will usually offset any skill that the welder may have. Careless preparation has caused many failures.

Bevelling—In making an autogenous weld, it is necessary that fusion penetrate entirely through the metal. In order to aid this the pieces are usually chamfered or beveled

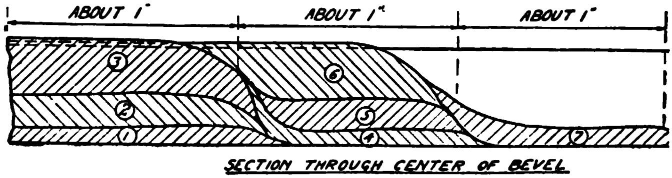


Fig. 172—PROGRESSIVE STEPS IN FILLING OF BEVEL

with an air hammer, a grinder or cold chisel. By bevelling is meant the grooving or chamfering of the metal at the line of the weld, the depth of this groove or V being equivalent to the thickness of the metal.

Bevelling is not required on castings or plates lighter than $\frac{1}{8}$ in. in thickness. From $\frac{1}{8}$ in. to $\frac{3}{16}$ in. in thickness

a narrow chamfer only is necessary; one in which the angle opening is 90 deg. is sufficient. From $\frac{3}{16}$ in. up to the maximum thickness weldable by the oxy-acetylene blowpipe, an angle opening of from 60 deg. to 90 deg. is sufficient, the angle being dependent somewhat upon the nature of the material and the location of the weld.

It is not sufficient to merely separate the edges, because in this case the upper corners will be melted down and will flow into the space between the pieces, adhering to the sides rather than fusing intimately. This does not produce a weld in any sense, as experience speedily shows.

Under certain conditions it is possible to use an oxygen cutting blowpipe for bevelling. In case this is done, care must be taken that all the oxide produced on the surfaces cut by the blowpipe be removed before welding.

Setting Up Work—Before starting to weld, it is necessary to adjust or arrange the parts to be welded, so that during the operation they remain in relatively the same position. It is a common fault of inexperienced welders to overlook this important item, and consequently the strength of the weld, as well as the progress of the work, will be seriously affected. In lining up a piece it is essential that the deviation from the original lines, caused by expansion and contraction, must be thoroughly understood and cared for.

In repairing castings of non-malleable nature, the adjustment before welding should be very carefully done. This adjusting is usually carried out by means of straight edges, jig clamps, keys, wedges and other devices.

Character of Flame—The combustion of acetylene in oxygen produces a two-phase flame. The luminous cone or jet indicates the following reaction:

$$C_2H_2 + O_2 = 2CO + H_2$$

The oxygen in this reaction is supplied from the cylinder. It is at this point that the endothermic energy of acetylene takes place.

The bushy non-luminous envelope indicates this reaction, the oxygen in this phase being supplied by the atmosphere:

$$2H_2 + O_2 = 2H_2O$$
$$2CO + O_2 = 2CO_2$$

The character of the oxy-acetylene flame depends upon the proportion of oxygen and acetylene contained in the mixed gas as it issues from the tip of the blowpipe. This proportion is controlled to some extent by regulators or other devices installed with the equipment. The final adjustment, however, should be with the needle valves of the blowpipe. The proportion of oxygen is approximately regulated by adjusting the oxygen regulator to the proper pressure. The acetylene is also regulated when using a medium pressure generator, or dissolved acetylene from tanks, by means of regulators and regulating devices. In the use of low pressure acetylene generators it is not necessary to use devices such as this, since the correct amount of acetylene is drawn into the blowpipe by means of an injector in the welding head or blowpipe.

The proportion of the gases may produce three divisions in the character of the flame—called reducing or carbonizing, neutral and oxidizing. The welder should at all times observe carefully the type of flame produced, and any divergence from the type desired should be instantly detected and corrected.

Reducing or Carbonizing Flame—When the blowpipe is first lighted the acetylene is greatly in excess. The flame produced is of abnormal volume, a dirty yellow color, and of uniform consistency. This is the reducing type in an exaggerated degree. By increasing the oxygen pressure the size of the flame is lessened, and gradually a white zone of greater luminosity appears near the blowpipe tip. This luminous zone is not yet clearly defined. The flame is still of abnormal size, is streaky in appearance, and a brilliant

white. The extent of the reducing or carbonizing action of the flame is judged practically by the size and definition of the luminous zone. When the luminous zone becomes more clearly defined and takes the form and color of a bluish white incandescent cone or pencil, the streakiness is diminished and the flame approaches neutral. The reducing flame is used to some extent on certain alloy steels, aluminum and nonferrous alloys.

Neutral or Normal Flame—When acetylene and oxygen are ignited in the correct proportions a neutral flame is produced. The appearance of this flame is characteristic. It is made up of a distinct and clearly defined incandescent pencil or cone of bluish green in color, surrounded by a faint purplish yellow secondary flame or envelope of bushy appearance. The incandescent pencil or cone may be from $\frac{1}{4}$ in. to $\frac{5}{8}$ in. in length, and is usually rounded or tapered at the ends. The maximum temperature of the oxy-acetylene flame is $\frac{1}{8}$ in. to $\frac{3}{16}$ in. beyond the extremity of this jet. In establishing a neutral flame the jet should be of the maximum size for the particular blowpipe head in use. This flame is established by gradually increasing the oxygen supply until the point at which the incandescent jet is of the greatest clearness is just passed, and then finally adjusting by decreasing the oxygen supply until the desired condition is obtained.

This type of flame is the one most extensively used, and no welder is proficient until he is thoroughly familiar with its appearance.

Oxidizing Flame—When an excess of oxygen exists in the welding flame it is called oxidizing. The effect of too much oxygen is to diminish the size of the flame, blunt or blur the incandescent cone, and produce a weak, streaky or scattering flame. The oxidizing flame has neither the size nor the illuminating qualities of the reducing flame, but the incandescent flame is slightly more pronounced. It is a

pale violet color. In some blowpipes the incandescent cone is not only diminished in size, but is slightly bulged at its extremity as compared to the normal flame.

Manipulation of Blowpipe—The blowpipe must be grasped firmly in the hand. It is not good practice to hold it in the fingers, because it is impossible to manipulate the flame with as great regularity and control, nor will it be possible to do as heavy work without tiring.

Occasionally the hose is thrown over the man's shoulder. In this case the weight of the blowpipe is suspended and held by the tubing, so that it is only necessary to impart the typical welding motion to the blowpipe, which can usually be done by the fingers. The movement of the welding flame is hindered, however; and this method is therefore not recommended, and should be used only as a relief when the work is of long duration and the operator's wrist and fore-arm become tired.

The head of the blowpipe should be inclined at an angle of about 60 deg. to the plane of the weld. The inclination of the head should not be too great, because the molten metal will be blown ahead of the welding zone and will adhere to the comparatively cold sides of the weld. On the other hand, the welding head should not be inclined too near the vertical, because the preheating effect of the secondary flame will not be efficiently applied.

There are certain cases, however, where the conductivity of the metal is such that it is not necessary to utilize this preheating; also certain metals have the property of absorbing the gases of this flame. Consequently, in these cases it is best that the flame impingement be concentrated to as small an area as possible.

The motion of the blowpipe should be away from the welder and not toward him, as closer observation of the work can be obtained and greater facility in making the weld will be experienced.

Where thin sheet material is being welded and it is not necessary to use a welding rod or wire, a weld may be produced by moving the blowpipe in a straight line. It can readily be seen that this does not apply to welds which have been bevelled, and which require the use of filling material, for in this case a swinging motion must be imparted to the blowpipe to take in both edges of the weld and the welding wire at practically the same time.

In comparatively light work a motion is imparted to the blowpipe which will cause the incandescent cone to describe a series of overlapping circles, the overlapping extending in the direction of the welding. In order that the weld be of a good appearance this must be constant and regular in its advance. The width of this motion is dependent upon the size of the material being welded and varies accordingly with the nature of the work.

In heavier work, if the above system were used, a great deal of the motion would be superfluous. Consequently either an oscillating movement, or one in which the jet of the blowpipe will describe semi-circles, should be used. This confines the welding zone; and while the progress is not so fast, it is more thorough than the other system for this class of work.

To the average beginner the regular control of these motions is difficult, and considerable practice is required to become skilled. It is the regularity of these motions that produces the characteristic even-rippled surface of good autogenous welding. The progress of a welder and the quality of his work can be determined to some extent by the skill with which he produces this effect.

After the swinging motions of the blowpipe have been mastered, the next step will be to introduce the welding rod into the weld in such a manner that the regular advance of the blowpipe will not be hindered nor retarded. It can be seen that there is quite a little attention needed to secure

perfect co-operation between the two hands, one controlling the blowpipe and the other adding the welding rod.

The welding rod should be held inclined at about 45 deg. In this position sufficient quantity of metal may be added at the right time. With the welding rod held in a vertical position or horizontal, the possibility of the addition of an excess of metal, part of which is not fused, is great. In adding this metal, care must be exercised that the edges of the weld are in the proper state of fusion to receive it. If the metal is not sufficiently hot, the added material will

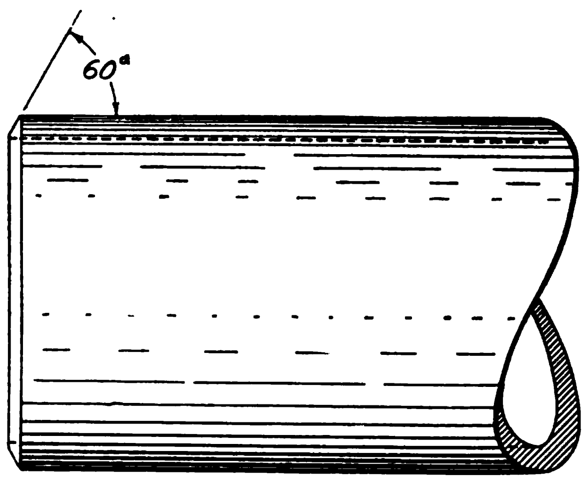


Fig. 173—PROPER CHAMFER FOR THE END OF GAS PIPE

merely stick to the sides and fusion will not exist. It is therefore necessary that, by the motion of the blowpipe, fusion be produced at the edges of the weld equal with that of the welding rod.

The usual faults of the beginner are failure to introduce the welding rod at the proper time into the welding zone, to hold the rod at the wrong angle, or to fuse either too little or too much of the rod. The filling material when melted

should never be allowed to fall into the weld in drops or globules. When the proper time arrives to add it, the welding rod is lowered into the weld until it is in contact with the molten metal of the edges. When in this position the flame of the blowpipe is directed around it, and thus fusion is produced.

It is customary to add metal in excess to that of the original section. There are several very important reasons for doing this. First, the weld is reinforced and the strength is accordingly increased. Second, in case a finished surface is desired a sufficient stock must remain to allow for finish. Third, small pinholes or blowholes may be found just under the surface of the weld, which do not extend to any depth and may be removed by filing or machining.

The application of the acetylene-oxygen blowpipe to welding gas mains is an important development which can be applied to both emergency and routine work. One of the pioneers in this work, J. D. Shattuck, of Chester, Pa., stated in *The Gas Age*, (Nov. 16, 1914, p. 470) that 'when a gas engineer comes to realize how great the leakage can become on a screw joint line or a rubber expansion jointed line, he will not be satisfied with anything less than a welded line.'

In the same article he gives the following practical details derived from their experience:

'**Welding Gas Mains**—Pipe in 40 ft. lengths is now available, both I. D. and O. D. The method of proceeding with the welding of pipe is simply the rolling of lengths and butting of the ends together in a fairly straight line. This can be done on a smooth roadway or on skids over the trench. After a few lengths are welded together the skids may be removed from the point of beginning and the pipe slowly reeled into the trench as the work proceeds, or the pipe can be welded in sections, with two or more gangs working at the same time, then dropped into the trench, and the final connection welded.

The more snake-like horizontally the pipe is laid in the trench the better, as it will tend to relieve what contraction strains may occur later. The pipe should be carefully graded, however, as in low pressure work. No care is necessary in dropping the pipe into the trench. The weld is as strong or stronger than the pipe itself,

and if the falling of the pipe into the trench is going to break a bad joint, obviously we are glad to discover such defect.

The advantage of welding on top is that the pipe can be slowly turned, thus enabling the welder to always work on the upper diameter of the pipe. The pipe can be welded underneath if necessary, as the fluxed material does not tend to drop but tends to hang to the pipe. By placing chain tongs on the pipe there is no difficulty in obtaining twist enough in the pipe to get sufficient roll, either forward or back, to make welding easy.

The end of a pipe of 2 in. diameter and over should be slightly chamfered about 30 deg. from the diameter of the pipe, so that when the ends of the pipe are butted there is a 'V' groove formed. This 'V' should not be more than 1/4 in. across the top. As the thickness of the metal becomes greater a good rule to follow would be that up to plates of 3/4 in. the width of this 'V' should about equal the thickness of the metal to be welded, but beyond that, the opening would not need to be in quite the same ratio.

Chamfered pipe can be purchased at an additional cost per length of 3 1/2 cents for 2 in., 4 1/4 cents for 3 in., and 8 cents for 4 in. pipe. To offset this, there is a 2 1/2 per cent saving in cost of plain end pipe over screw end and coupling. In welding two ends of pipe together Norway iron is used. It is necessary to make the pipe fairly straight to weld a small portion on one side of the pipe, and then a small portion directly on the opposite side, thus tacking the pipe together and then completing the weld.

A welder and two assistants, the assistants to roll the pipe, are all that is required to make the joint of ordinary sizes. After the completion of the weld the welder, by means of a small hand truck, moves his two tanks forward to the next job, while the helpers are rolling the next pipe into position. We have designed a small galvanized truck, which can be locked at night, and shades the tanks from the hot sun during the day.

If a small hole is burned in the main, ream it out and drive a steel plug in the hole, and with a little care it may be welded over. To make sure there is no leak in the welding of the socket to the main, the latter can be connected to the oxygen tank and pressure put on the socket, or a cylinder of compressed air can be carried for testing services.

A number of interesting experiments were made to determine the effect of burning holes through the main. With a small hole the gas was easily extinguished by the use of a wet blanket. With a large hole, where the flame spreads so that it is not safe to approach close

to it, a piece of 4-in or 6-in. pipe, large enough in diameter to cover the hole, and 12 ft. to 15 ft. long, is held upright over the flame, combustion then taking place at the end of the pipe. The pipe can be thrown over quickly or moved horizontally away from the line, thus carrying the flame with it, and extinguishing the fire at the main. A 1/8-in. hole in the main at 3 lbs. pressure will blow out the low pressure torch. A 1/4-in. hole requires about 10 lbs. to blow out the torch.

In case the line is under asphalt or expensive pavement, a split sleeve can be employed. With this steel sleeve the expansion joints may be completely covered. The sleeve is welded horizontally, first on one side, then turned and welded on the other, and then completed at the ends without interruption of service.

Strength of Welds—The Testing Bureau of Swarthmore College made a number of tests for us of pieces of pipe welded in the field by our men without any special care. They found that not only is the weld stronger than the pipe, but the stretch in the pipe without rupture is a great many more times than any possible temperature contraction force that would occur to this pipe after it was welded and in the ground. In other words, no provision need be made to take care of temperature contraction in a welded line so far as the line itself is concerned. If steel valves are used, the valves will stand the strain. The bolts, however, that bolt the flanges to the valves may stretch enough to cause a leak unless some provision is made at this point. Slack should be forced into the line at and near valves. The best way to make sure that such extra length has been forced into the line is to lay the line, bolting the valve flanges together without the valves, and then lifting the line back of the proposed valve location until the flanges are separated far enough to insert the valve. After inserting the valve drop the line back into the trench.

According to the Bureau of Standards at Washington the coefficient of expansion of welded boiler tubes between 0 deg. C. and 200 deg. C. was found to be:

Charcoal iron	0.00001235
Bessemer steel	0.00001258
Seamless open-hearth steel (hot finished)	0.00001239

The expansion of lengths of 100 ft. pipe, given by the *Practical Engineer* (January, 1911), up to temperatures and including 125 deg. fahr., are as follows:

Temperature	Cast Iron	Wrought Iron	Steel
50 deg. fahr.	0.36 in.	0.40 in.	0.38 in.
100 deg. fahr.	0.72 in.	0.79 in.	0.76 in.
125 deg. fahr.	0.88 in.	0.97 in.	0.92 in.

The physical properties of ordinary steel are as follows:

Tensile strength............52,000 to 62,000 lb. per sq in.
Elastic limit................ Not less than 30,000 per sq. in.
Elongation in 8 in..............Not less than 20 per cent.
Reduction in area..............Not less than 50 per cent.

The tests made by Swarthmore College show that the contraction of a long length of pipe would have to occur at one point to cause a rupture of the pipe. Therefore I feel that we are fully justified in not providing for expansion in laying welded lines under ordinary conditions, where the temperature changes at 3 ft. below the ground cannot be greater than from 32 deg. minimum to 75 deg. maximum, a range of only 43 degrees.

We have used lead gaskets under service saddles and between valve flanges. Welding the service to the main will do away with these lead gaskets. In very cold climates where the frost gets down to the saddle, every year a number of companies have had leaks at this point, and outside of the money saved, I believe welding of services will do away with this other element of leakage. It is a question whether the gaskets used on the valve flanges should not be of some other material than lead. This is the only point where we have not thoroughly eliminated the possibility of leakage on the mains. Companion valve flanges are made up with short pieces of pipe welded to the flanges to avoid screwed joints.

Wrought iron or steel pipe 12 in. and smaller can be bent cold in the field, provided the radius of the bend is not less than given in the following table. Any radius less than that is apt to cause the pipe to buckle.

Safe Radius of Bend

Size of Pipe,	Advisable	Maximum	Size of Pipe	Advisable	Maximum
2½	15	10	10	60	40
3	18	12	11	66	44
3½	21	14	12	72	48
4	24	16	13	84	60
4½	27	18	14	90	68
5	30	20	15	100	76
6	36	24	18 O. D.	125	90
7	42	28	20 O. D.	158	120
8	48	32	22 O. D.	163	132
9	54	36	24 O. D.	180	144

In his excellent article upon "Welding in Gas Distribution," *The Gas Age*, (October 1, 1914, p. 316), D. E. Keppelmann, of San Francisco, gives many practical details derived from their extensive experience, and his descriptions of their methods may very properly find a place here.

Welding Operations—The oxyacetylene welder must select the proper size of torch and heat back on the metal far enough to retain full welding heat on the edges, and by slightly tipping the torch avoid overheating of the thin parts, at the same time supplying the excess heat to the thicker parts. He should also apply his filling material at as low heat as possible, or more correctly, fill in new material only when the edges of the scarfs are sweating or fused properly. This is especially important in welding heavy material. It will often prove of value even in steel welding to arrange a suitable method of preheating in order to check the loss of the heat, either by a row of gas or oil burners placed on each side of the weld, or a charcoal fire extending over the inside lower part of the object welded.

A horizontal weld can be done many times faster than the vertical or overhead weld where the material must be carefully spread and filled drop by drop. An experienced boilermaker, for instance, can and must be able to fill in his metal without losing molten metal, as a failure in this respect in a cramped and close position may mean serious burns.

The ability to make a thoroughly sound overhead weld without a spill of molten metal can be considered a satisfactory test of a steel welder, it being impossible for him to accomplish this task without a sufficient knowledge of welding wrought steel. Welding of cast iron requires special flux and filling rods, exceptionally clean and rich in silicon. Cast iron can be welded very satisfactorily, the greatest difficulty being in properly taking care of the expansion and contraction.

In large installations open as long a trench as the law will permit. Pipe in sizes 2 in., 3 in. and 4 in. should be welded beside the trench; 6 in., 8 in., 10 in., 12 in. and 16 in. must be welded directly over the trench on timber laid across the trench; two by fours for 6 in., four by fours for 8 in. and 10 in., and six by sixes for 16.

Assuming 8 in. pipe, 40 ft. to the length, the pipe is placed length after length upon the cross timber over the trench for the entire distance of the trench. The first two lengths are butted together square, end to end, care being taken that both lengths are level. The pipe being chamfered about 45 deg. forms a groove when the lengths are brought together. If the pipe is not chamfered, leave a space between the end of the pipe, varying from $\frac{1}{16}$ in. to $\frac{1}{4}$ in., according to the size of the pipe being welded. All pipe, however, should be chamfered, to insure a better and more economical weld, requiring less labor, oxygen, acetylene and welding steel, and insuring a fusion to the inner wall of the pipe.

The operator now applies the flame to both ends of the pipe at the bottom of the groove, bringing it to a cherry red heat, as well as both ends of the pipe a distance of $\frac{1}{2}$ in. back of the groove, simultaneously applying additional Norway or Swedish iron, which is furnished in the shape of rods $\frac{3}{16}$ in. in diameter—that about 4 ft. long being the most convenient. The operator continuously applies the flame in an oscillating or rotary movement, causing a fusion as between the ends of the pipe and the rod of iron, which gradually melts into a puddled molten mass, filling in the groove. Care must be exercised, never permitting the steel rod to be removed from the pipe during fusion, as it would be quickly burnt.

Fig. 174—WELDING LOW PRESSURE MAINS.

The welding is done on the top surface of the pipe and gradually rolled by two helpers, located on each far end of the pipe. As the operator welds, the helpers roll the pipe on the timber, permitting the operator to weld on the top surface of the pipe at all times, which permits of the weld being done with great rapidity. The weld completed, the two lengths welded together, has reached the end of the timbers across the trench, when another length is added, the helpers rolling the pipe on the timbers as the operator welds, which,

after the weld is again completed, brings the pipe back to the opposite side. This operation is continued, adding as many lengths as are desired.

Always roll the pipe away from the operator, this being preferable, for the reason that the force of the flame piles the molten metal into a semi-circle over the joint, making a stronger weld; the flame held at an angle of about 45 deg. having a tendency to do so without any particular assistance on the part of the operator. This method of procedure will also drive any possible existing impurities to the top of the molten mass in the form of slag, which readily scales off when the weld cools. Lengths of pipe are added until an obstruction occurs in the trench which would not permit of the pipe being laid, or until the length is too great for the helpers to turn. Two helpers with chain tongs will turn as much as 30 lengths of 8 in. pipe, or 1,200 ft. welded together.

When an obstruction occurs, or the lengths are too many for further rolling, the timber is pulled from beneath the pipe, the pipe falling to the bottom of the trench. No care is exercised; rather the pipe is deliberately thrown into the trench, it being desirous that any imperfect welds show up at this time. At the end of these great lengths a bell hole is dug of sufficient size to admit the operator who welds the lengths together.

When it is impossible to turn the great lengths, the operator is compelled to weld around the pipe as it lies in the trench. One would imagine, when the operator is welding on the bottom of the pipe in the trench, that the molten metal would drop away from the contemplated weld. Such, however, is not the case; not a drop is lost, for the intense heat of the flame quickly melting the rod, the force of the flame drives the molten metal into position, and the operator continuously moving the blowpipe permits the weld to partially chill, sufficiently so to hold the metal in place.

Welding in the bell hole is done just as well as on top, although, quite naturally, not as rapidly as welding continuously on top. To expedite the work, the operator is materially assisted by mounting the tanks on an inexpensive carrier, the frame of which consists of pipe welded together and mounted on wheels, or if at any great distance, the entire outfit may be placed in an automobile. A long length of welded main in the trench will appear in a snake-like position; no attempt should be made to straighten it out, for this is a feature essential to provide for any possible expansion or contraction. No other provision for expansion or contraction is made,

it being deemed unnecessary, and our past experience proves this contention.

Lateral Mains—When laterals are necessary, a pipe is welded to the main line at any angle required, eliminating special fittings. Herein is a tremendous saving in installation costs. No specials are required in advance, no delays incurred waiting for specials and no leaks encountered after specials are installed. These fittings are made of the pipe at the time required and welded into position at 50 per cent less cost. Invariably special fittings are made of pipe that had been previously junked and apparently useless; with welding, however, nothing is wasted.

All welded pipe is subjected to a test with air at a pressure of 150 lb. to the sq. in. After gauge readings, showing the line to be tight at the end of 24 hours, the usual soapy water is applied to each joint for further assurance of the absolute tightness of each joint.'

Practically any size of line can be laid with one or more crews of three men each, one man to line up the pipe, one to turn it and one welder.

The simplest method of lining up the pipe and undoubtedly the best is to use 2-inch x 4-inch timbers or wedge blocks. The pipe should be lined up and welded at the side of the trench and far enough from it to permit of the pipe being turned half its circumference toward the open trench. Twenty standard lengths or about 400 feet of 8-inch or 1000 feet of 4-inch can be turned by one man with chain tongs, without putting too much strain on the weld. Such a length of pipe, of course, could not be handled over rough country. The pipe should be turned half its circumference each way, towards and away from the trench.

A line up to 10 inches diameter may be laid without expansion joints although 4-inch, 6-inch and 8-inch are more flexible, permitting more readily sufficient slack to be pushed back or "snaked" into the trench, to take care of all expansion and contraction, which might otherwise cause the line to break. Sizes above 8 inches should have an expansion joint about every eight lengths or 160 feet."

When welded lines are to be installed to carry a high pressure, such as on the discharge of the high pressure com-

pressor, the "saw tooth" joint is the better to adopt in welding. It makes a much stronger joint than the butt welded one and is less liable to blow up while in service.

Nearly all "blow-ups" in oxy-welded high pressure gas lines have occurred at a butt-welded joint.

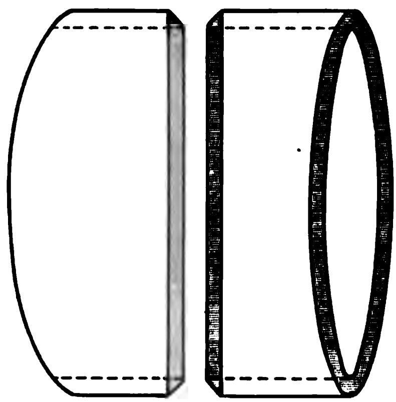


Fig. 175—BEVELED JOINT

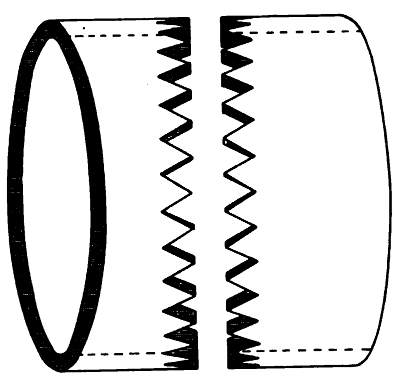


Fig. 176—SAW TOOTH JOINT

TABLE No. 79
OXY-ACETYLENE WELDED PIPE LINE COSTS
Average Cost of Welding High Pressure Gas Pipe as Given By Some of the Smaller Gas Companies*

Size of Pipe	No. Joints 1 Welder per Day	Cost Welding per Joint	Cost Labor Placing and Turning Pipe	Total Cost per Welded Joint	Cost Plain End Couplings
2 in.	100	$0.10	$0.10	$0.20	$0.53
4 in.	50	.21	.18	.39	.69
6 in.	33	.37	.25	.62	1.29
8 in.	24	.53	.35	.88	1.49
10 in.	20	.65	.40	1.05	2.09
12 in.	15	.85	.45	1.30	2.79

Comparative Costs as Given by Pacific Gas & Electric Co.

2 in.	3 min. per joint	$0.09	$0.09	$0.18	$0.53
4 in.	6 min. per joint	.18	.16	.34	.69
6 in.	10 min. per joint	.27	.25	.52	1.29
8 in.	15 min. per joint	.37	.33	.70	1.49
10 in.	16 min. per joint	.44	.36	.80	2.09

Cost of Laying 6, 8, 10 and 12 inch Oxy-Acetylene Welded Pipe**—March, 1918

	6 in.	8 in.	10 in.	12 in.
Survey............ per foot	.037	.043	.055	.065
Trenching........... per foot	.10	.116	.132	.16
Laying.............. per foot	.0425	.052	.091	.1595
Back Filling......... per foot	.05	.058	.065	.0797
Welding............ per joint	.52	.70	.80	.88

Welding Costs Made Up as Follows†

	Oxygen	Acetylene	Labor Welding	Cost Labor Placing and Turning Pipe	Steel
6 in.	3½ cu. ft.	3½ cu. ft.	10 min.	0.245	½ lb.
8 in.	4 " "	4 " "	15 min.	0.33	¾ lb.
10 in.	5 " "	5 " "	16 min.	0.365	1 lb.
12 in.	8.53 " "	8.53 " "	21 min.	0.41	1¼ lb.

*Courtesy of Davis-Bournonville Co.
†Courtesy of the Southern California Gas Co.

PART THIRTEEN

DOMESTIC METER

FLAT RATE—INSTALLING METER—METER HOUSE — DISCONNECTING METER — PROVING — REPAIRING METERS — CONTINUOUS METER READING—CAPACITIES—TIN METER PARTS—STANDARD PROVER—CUBIC FOOT BOTTLE—ERRATIC METERS.

Flat Rate System—Changing from a flat rate system to a meter system will result in a saving of from sixty to seventy per cent of the gas previously consumed. This great difference can be attributed to various causes, principally as follows: On a flat rate system consumers will invariably use cheap, wasteful burners; they will drill out the mixer when the pressure is low in an endeavour to get a larger supply; they pay no attention to turning off the gas when work is finished or the temperature of the house is sufficiently high; and when the temperature does get too high, the tendency is to open the doors and windows in preference to turning down the fire. In fact, fires and lights are left burning night and day. All of these practices do the consumer no good and waste thousands of cubic feet of this ideal fuel. It should be borne in mind that gas is a luxury and should not be wasted.

With a meter installed, it is an easy matter to test piping for leaks by turning off all fires and lights and noting by the small dial whether there is any gas passing through the meter. This is impossible on a flat rate.

With a meter system the life of any gas field will be prolonged several years over a flat rate system.

Domestic Gas Meter—All things considered, the gas meter is the most reliable measuring instrument made. This may be a startling statement; nevertheless, it is true. If,

in a test for accuracy, one hundred of the best watches were compared with one hundred gas meters, for one, two, three or more years, both operating under the same conditions, *i. e.*, exposed to the action of gas, heat, cold, etc., the average registration of one hundred meters would be more accurate than that of the one hundred watches.

The following is a brief description of the tin gas meter shown in Fig. No. 181. The diaphragms — two in number—are in the lower part of the meter; the valves and fittings in the upper part. The index registers the quantity of gas delivered by the meter.

The principle of a gas meter can be readily understood. We are all familiar with bellows such as are used at fireplaces. Let us assume a pair of bellows is empty; then that the handles are extended and the bellows filled with air. If the handles are afterwards brought together the air is expelled. If a stop be placed on the bellows, both when closed and when opened, they must make a certain fixed stroke and receive and give out a fixed quantity of air with each motion. The diaphragm of a gas meter does the same thing. It receives a certain fixed quantity of gas and then expels it, having the same stroke every time. By means of the attachments in the meter each stroke is registered and translated into cubic feet on the index, which is a simple piece of geared mechanism by which the cubic feet are recorded by the thousand. In a gas meter there are two diaphragms or bellows, as only one would give an intermittent supply.

The gas meter may also be likened to a steam engine. Steam is admitted through the slide valves of an engine, the valves being of the same kind as are used in gas meters; the piston is pushed forward and a certain amount of steam admitted to the cylinder—the cylinder of the engine corresponding to the diaphragm of the meter. Steam is then taken on the other side of the piston and the piston pushed back again. Each complete stroke requires or takes a given,

fixed quantity of steam. Knowing the quantity of each stroke, the steam could be registered in thousands of cubic feet, if it were desired to do so, as gas in a meter.

The steam engine is also similar to the gas meter, in that the steam would rather not work the engine if it could help it. If there should be a leak in the valve, around the piston rings, or elsewhere, the steam would pass out, as it would be easier than pushing the engine. It is a well-known law of physics that fluids will take the path of least resistance. Gas acts the same way in the meter, having a tendency to pass through without working the bellows if it can find any point for leakage. For this reason the general average of gas meters is slow, or against the gas company.

Prepayment, or "slot," meters are regular meters with a mechanical attachment so that coins can be inserted and a proportionate amount of gas purchased. A valve closes gradually, to give warning, when the gas paid for ha been consumed.

It is the custom of gas companies to inspect meters regularly and so keep them in good condition. This practice is a protection to both the consumer and the company. Records are kept of the test on each meter, and it is surprising how close the results are. It can be safely said the average net result is slow, or in favor of the consumer, and, at the same time, this average error is less than 2 per cent. It is a fact of public record that the bulk of meters, even when complained of, will show slow registration. Some few meters register fast, owing to mechanical imperfections, which cannot be entirely avoided in any mechanical appliance; but the total number of fast meters, in proportion to all meters in use, is relatively insignificant. This statement can easily be verified from the records of city or state meter inspectors anywhere in the United States or throughout the world.

Many people, without thinking about the matter, believe that gas is wrongfully charged to them; this is a mistake. Gas meters are made by manufacturers who specialize in this work, and these manufacturers do not send out incorrect meters; in fact, they take as much professional pride in their product as do the makers of watches or clocks. The workmen who prove the meters are also sworn to let no meter pass if it is not correct. Some law suits have occurred over gas bills, and, after scientific testimony, the meter has been upheld in every case.

There are several reasons to account for the popular distrust of gas meters. One is that very few are familiar with the principle of a meter, and without knowledge of its construction they do not realize that the meter is a scientific measuring instrument. Another reason is that bills are usually paid after the gas has been consumed. People pay more willingly for what they have on hand yet to be used than they do for material or commodities already used, as is the case with gas. Another reason is that the meter will always deliver gas when called upon and not forget to record it. Very few people remember how many lights have been burned, or how long the gas stove has been used during the month. Dark and cloudy weather causes greater consumption, and in severely cold weather people stay at home and gas heaters are used more frequently and continuously. Other things affect gas bills which, in reality, are under the control of the householder. A dark wall paper, for instance, will absorb light, while a light coloring will reflect it.

Income—The average annual income of a domestic meter in small cities where natural gas sells for 25 cents per thousand cubic feet is approximately $30. In large cities the average will be slightly higher. The foregoing is true in the southern as well as in the northern states.

TABLE No. 80

Table Showing Number of Domestic Meters Required for Towns and Cities of Different Population, Approximate Amount of Gas Required to Supply Same on the Coldest Day and the Approximate Income with Gas at 25, 30 and 35 Cents per Thousand Cubic Feet.

*Population	Number of Meters	Approximate Amount of Gas Required for Coldest Day Cu. Ft.	Approximate Annual Income		
			At 25c per 1000 Cu. Ft.	At 30c per 1000 Cu. Ft.	At 35c per 1000 Cu. Ft.
1,000	200	200,000	$ 6,000	$ 6,800	$ 7,400
2,000	400	400,000	12,000	13,600	14,800
3,000	600	600,000	18,000	20,400	22,800
4,000	800	800,000	24,000	27,200	29,600
5,000	1,000	1,000,000	30,000	34,000	37,000
7,000	1,400	1,400,000	42,000	47,600	51,800
10,000	2,000	2,000,000	60,000	68,000	74,000
15,000	3,000	3,000,000	90,000	102,000	111,000
20,000	4,000	4,000,000	120,000	136,000	148,000
25,000	5,000	5,000,000	150,000	170,000	185,000
30,000	6,000	6,000,000	180,000	204,000	222,000
40,000	8,000	8,000,000	240,000	272,000	296,000
50,000	10,000	10,000,000	300,000	340,000	370,000
60,000	12,000	12,000,000	360,000	408,000	444,000
70,000	14,000	14,000,000	420,000	476,000	518,000
80,000	16,000	16,000,000	480,000	504,000	592,000
90,000	18,000	18,000,000	540,000	612,000	666,000
100,000	20,000	20,000,000	600,000	680,000	740,000

*No allowance made for colored population.

Reading a Domestic Gas Meter—If people would read the registration on the index of their meter the correctness of their bill as rendered by the gas company would be more generally accepted. The accompanying view represents the ordinary type of index as generally used in gas meters. In reading, always take the last figure the hand or pointer has passed, and always read the numerals in sequence, beginning with the highest dial on the index.

Remember when the pointer is between two figures always take the smaller figure. It is never necessary to reset a meter index. When the finger on the circle of highest denomination has made a complete revolution, all fingers will correspondingly revert to zero, and the entire index will, therefore, automatically reset itself. In reading an index keep a record of the amount of gas consumed, and on taking the next reading deduct the previous amount. The difference will represent the amount of gas consumed in the period between the present and the previous reading of the meter.

TO READ YOUR METER

Each hand moves in a different direction. Read the figure that the hand has actually passed, beginning with the dial to the left—add two ciphers to the right of your figures.

DIAL AS ABOVE READS 108,400

Subtract the last month's reading from the present index and the difference will be the gas used to date in cubic feet.

Fig. 177—CONSUMERS' INSTRUCTION CARD FOR READING METERS

If in doubt about the accuracy of your meter, ask the gas company to test it, and be present at the test if you wish. The method of testing or proving is simple and easily understood.

Continuous Meter Reading—This system has many advantages in favor of both the consumer and the gas company.

Primarily where gas companies formerly required six meter readers to complete the work in the last few days of the month they would need under the new system but one who would be reading meters from twenty to twenty-five days a month. The one reader would naturally become more proficient and less liable to make mistakes, working continuously, than the greater number working but a few days each month.

With the old system it was often necessary to retain men throughout the month even though they had little other work to do, in order to have competent meter readers. This was an unnecessary expense but could not be very well avoided.

It prevents inconvenience to the public by doing away with the "waiting line" at the gas office so common on the 10th of the month.

It does away with the extra clerks necessary to receive the money during the last day of discount under the old system.

There is practically no difference to the consumer as the meter is read on the same date each month.

Capacity of Domestic Meters—The true method of judging the maximum capacity of meters is by determining the amount of gas a meter will pass with a certain intake pressure and a certain discharge pressure while the meter is connected in a service line working under conditions similar to those found in the average house. The average range of low pressure in domestic service is from 4 to 8 ounces and it is essential to deliver gas to the stove or range at about three ounces pressure. Consequently, in selecting the proper size meter, it is good policy to determine the capacity by what the meter will pass with a four ounce pressure on the intake or inlet and a three ounce pressure on the discharge or outlet.

While one may compare the open flow capacities of different makes of domestic meters, it is impossible to judge the rated capacity under working conditions by this method.

Open flow capacity means the amount of gas or air a meter will pass under certain intake pressure and with the discharge open into the atmosphere.

Installing Domestic Meters—Do not install a domestic meter outside of a building unless absolutely necessary. If it is found necessary to do so, it should be covered with a small box or house especially built for it. A metal box can be constructed so as to permit the use of a seal on the box and connections to the meter. This will decrease the liability of any tampering with the meter. An opening can be made in the metal box so that the dial can be read without removing the box. Fit over this opening a cover or lid similar to that used on tin meters.

The meter should be set in a dry place, preferably on a shelf, with the dial facing away from the wall. In cities having street car service, do not set the meter near any water or artificial gas pipes.

In case gas has previously been used in the building, see that the stop cock or valve back of the meter (inlet side) is shut off; also see that the shelf and meter connections are in good condition.

Turn the gas on at the curb stop-cock first.

Go through the house or building and examine all lines and connections from the meter to see that there are no openings. Do not take the word of anyone in regard to this, but examine them personally. If any connections are found open it is better to cap or plug them at company expense. Then turn the gas through the meter and watch the foot or index hand for five minutes to ascertain whether the lines through the building are tight. If they are not tight, shut off the gas at the street. If they are tight turn on the gas, light the fixtures in the house, making sure that the

air is all forced out of the house lines, and that the gas supply is good, and watch the meter to see that it registers. See that there are no unions or connections back of the meter other than the regular meter connections. Test connections

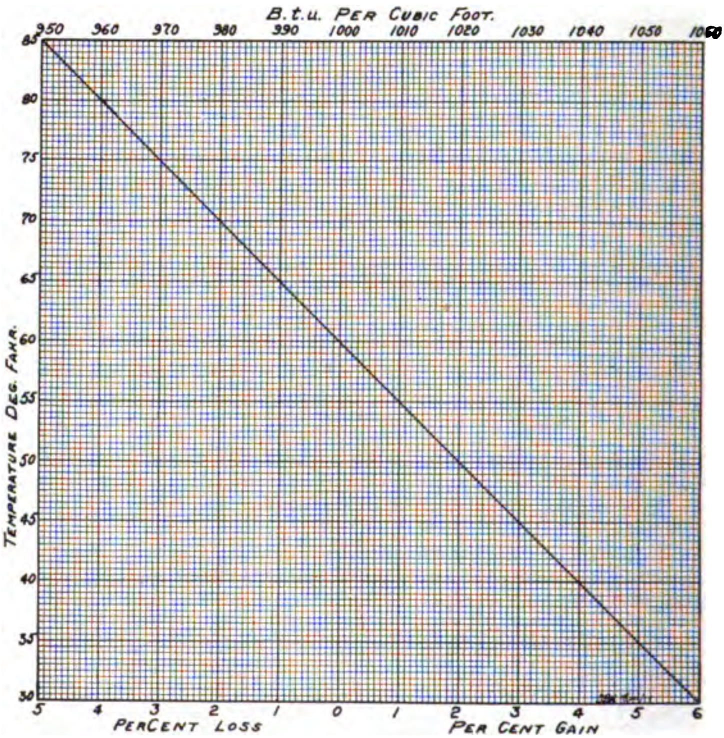


Fig. 178—CHART SHOWING THE CHANGE IN B. t. u. IN ONE CUBIC FOOT OF GAS OF 1,000 B. t. u. ABOVE OR BELOW 60 DEG. FAHR. TEMPERATURE

and meter for leaks. Take the number and reading of the meter just before you set it.

Meters should be set with the clock box properly sealed and with cap lock boxes on the inlet meter connection.

The gas must not be turned on at the meter under any circumstances when the occupants of the building are not at home.

A meter setter or reader must not enter an occupied house or building which is locked or try to gain admittance with a skeleton key.

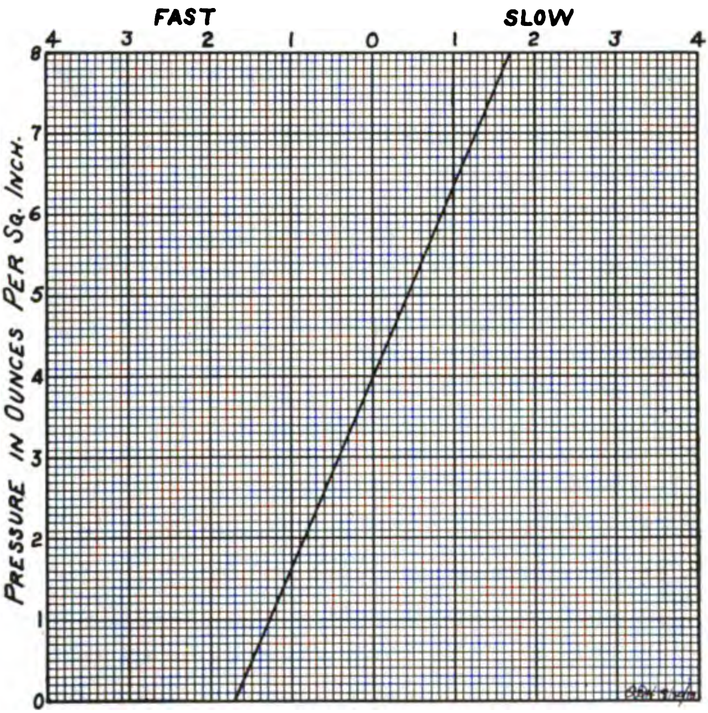


Fig. 179—CHART SHOWING PERCENTAGE FAST OR SLOW WHEN GAS IS MEASURED AT LOW PRESSURES OTHER THAN 4 OUNCES, WHICH PRESSURE IS TAKEN AS STANDARD

Disconnecting Domestic Meter—Examine and find out the number of meters on the service line. Shut off the gas at the curb and try to light a fire in the house to see if it is shut off.

Shut off stop-cock back of meter, that is, on the inlet side of the meter. Remove the meter, capping or plugging the end of the service line. Take the number and state of the meter. Great care should be taken in securing the name of maker, size, number and meter reading. Reports must be made out on the premises.

In apartment houses where there is more than one meter and the gas cannot be shut off at the curb, shut the stop-cock back of the meter, plug the opening in the header, and seal the stop-cock.

In houses where there is only one meter on a service, the meter must not be removed under any circumstances until after the gas has been shut off at the curb. If, for any reason, the curb stop can not be shut, do not disconnect the meter, but return the "disconnect order" to the shop or office, noting on same, in writing, the reason why curb stop-cock cannot be closed. The foreman should see that the curb box or stop is repaired at once and meter removed.

In case a building is being torn down, if the cellar wall is in good condition and is not going to be disturbed, shut off the gas at the curb, and plug or cap the service in the cellar. Where the wall is being disturbed, cut the line and plug the stop-cock at the street box until new building is completed. Foreman should keep a record of all buildings torn down and services plugged until they are restored to usual conditions.

All stop-cocks on the inlet side of meters should be locked with a stop lock and all inlet meter connections should have a cap lock box.

Street or curb boxes should not be installed without a base. The base prevents the box being jammed onto the service line and injuring it.

Where one or more buildings are supplied from the same connections to a street main, separate stops and curb boxes should be placed on each line, as nearly in front of the buildings as is possible.

Meter setters or inspectors should not use a light in looking for leaks or making inspections. Use a large-necked bottle with soap suds. Apply suds with a small brush.

Before leaving unfinished street work for the night, the foreman in charge should see that at least two red lanterns are burning at all ditch openings or street obstructions. If the ditch can be closed with an hour's overtime work, it is better to complete the work than to leave.

Repair all leaks on company lines at once. If unable to do so, report to the office in writing as to location and size of leak.

Do not set meters where they are difficult to read or to change. Dials should be set at zero at the meter shop where they can be properly sealed.

Treat domestic consumers in a courteous manner. Give consumers all possible information that will tend to better the conditions of their heating, lighting, or cooking appliances.

Curb Meter—The installation of a domestic meter on the service line at the curb is gradually becoming popular with the gas companies in the southwest where the climate permits it. The meter carries the index on the top with a dial facing upward. It is installed in a cast iron box with a cover bolted down by a specially designed cap screw. Underneath the cover is a gasket which keeps out the moisture.

There are great many advantages in this installation. One of them is that the meter reader can always get a reading regardless of whether the occupant of the house is at home or not. Another advantage is, that should there be any leakage of gas on the service line, it could be very readily determined by closing all valves on stove and gas fixtures in the house and by watching the meter. It also has a tendency to reduce the line loss or leakage of a distributing plant. If this type of meter installation was used throughout the distributing plant, it would be quite a factor in keeping down the percentage of leakage or line loss of the plant.

At this writing there are no meter companies suppling cast iron boxes for meter installations as described above. There are several types of domestic meters that are now made with the index placed on top and the dial facing upward.

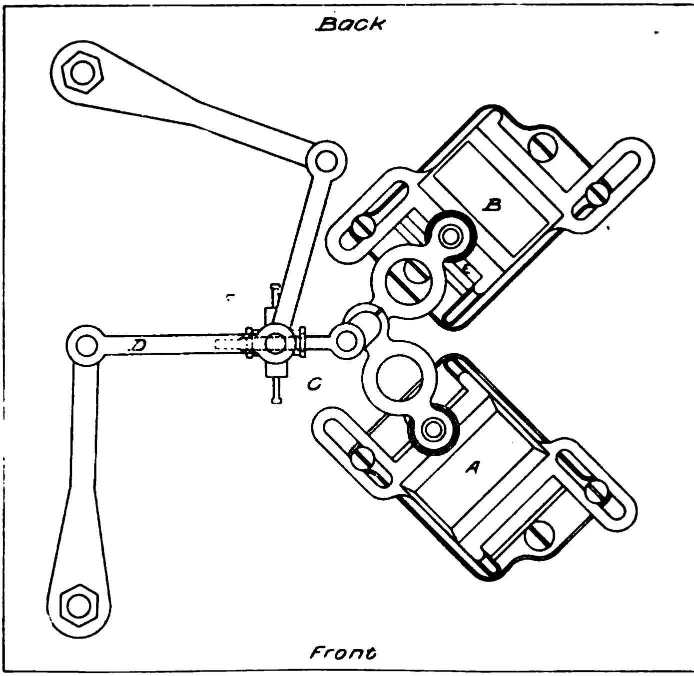


Fig. 180

Instructions for Setting Valves in Tin or Slide Valve Meter—Set the back valve cover "B" so that the port "E" to the diaphragm is completely open, and the front valve cover "A" is covering both ports of its seat.

Then the tangent "C" should be soldered so that it will be in a straight line with the link "D" as shown at "F."

Above instructions are for right-hand meters. For left-hand meters reverse the positions of valves "A" and "B."

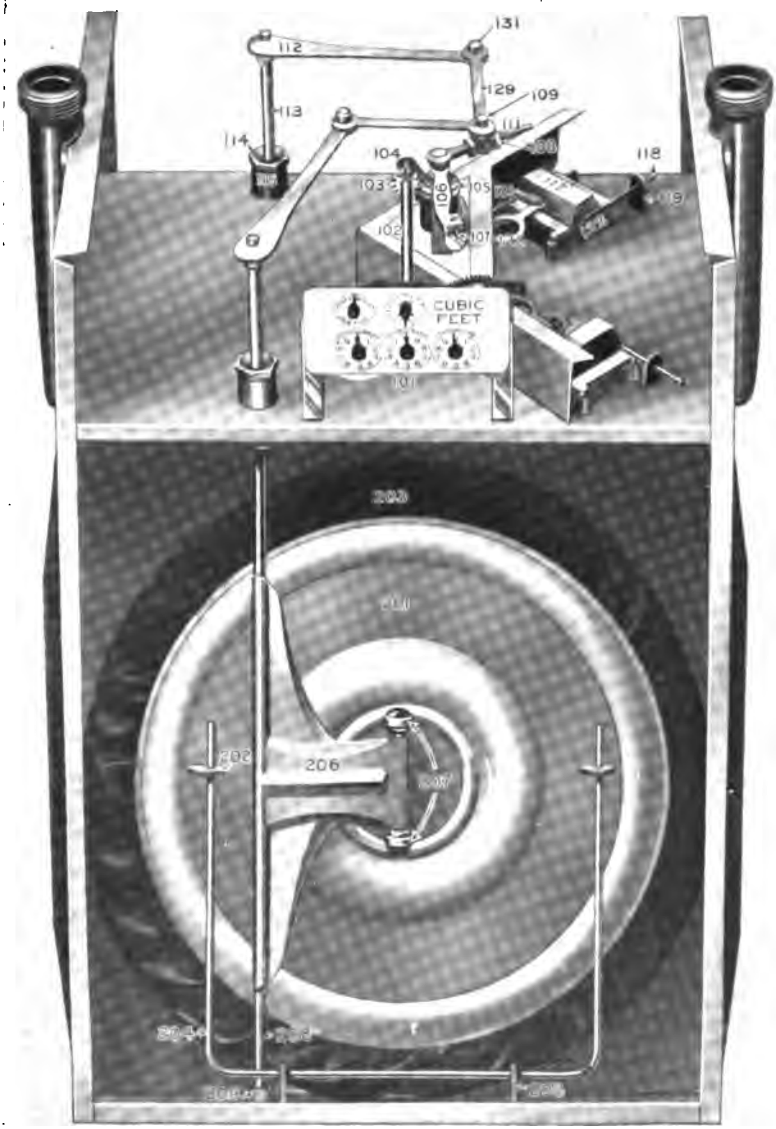


Fig. 181—INTERIOR VIEW OF GLOVER TYPE DOMESTIC METER

TABLE No. 81—LIST OF TIN METER PARTS

Number in Diagram on Figure 181

101 Index
102 Axle or Index Shaft
103 Axle Wheel or Index Shaft Wheel
104 Axle Bearing or Index Shaft Rest
105 Worm
106 King Post or Crank Frame
107 Click
*108 Tangent Jamb Nut
*109 Tangent Post or Bat
*110 Tangent Post Pin
*111 Tangent Arm
†112 Long Flag Arm
†129 Short Flag Arm
113 Flag Wire (same as 208)
‡114 Flag Stuffing Box Cap
‡115 Flag Stuffing Box
117 Valve Cover
118 Valve Cover Wire
119 Valve Cover Wire Guide
121 Valve Wrist and Pin
122 Valve Link
123 Valve Seat
129 Short Flag Arm
130 Crank
131 Flag Arm Rivet
132 Crank Stuffing Box
134 Crank Stuffing Box Cap
201 Disc
202 Disc Guide
203 Diaphragm
204 Disc Wire
205 Disc Wire Bracket
§206 Flag
§207 Rock Shaft and Carriage
208 Flag Wire (same as 113)
209 Flag Wire Step

*Parts Nos. 108, 109, 110 and 111, Tangent complete.
†Parts Nos. 112 and 129, Flag Arm complete.
‡Parts Nos. 114 and 115, Flag Stuffing Box complete.
§Parts Nos. 206 and 207, Flag complete.

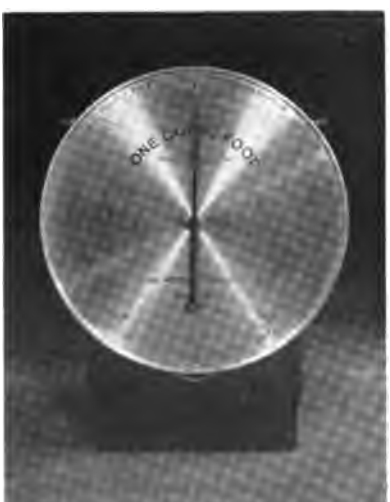


Fig. 182—TIN METER WITH ONE-FOOT DIAL

Rating of Tin Meter Capacities—The first rated capacity of meters was based on the then Standard English Burner, consuming six cubic feet an hour.

Under this rating the hourly capacity of a three-light meter would be 3 x 6, or 18 cubic feet.

A five-light meter, 30 cubic feet, and

A ten-light meter, 60 cubic feet.

Others in proportion.

While the meters as made to-day still have the original rating and are proved under this rating as required by law, it is by no means their actual working capacity, which is now generally determined by the amount of gas which they will pass under a certain differential in pressure, usually five-tenths, with a one and one-half-inch or two-inch water pressure on inlet of meter.

Repairing and Proving Iron Meters of Tin Meter or Glover Design—The foregoing information, with the exception of that part which describes "tearing down," removing diaphragms, testing case for leaks, and assembling, applies to the standard type of iron meter of Glover type design, *i. e.*, slide valve, and sewed (not formed) diaphragm.

The diaphragms are sewed and wound on tin rings in the same manner as with the tin meter. To remove them it is necessary to use a small wrench or pair of pliers to take out the small cap or plug than to unscrew the screw holding the spider which holds the diaphragm to the back wall or center partition of the meter. It is not profitable to purchase new leathers and rewind them on the rings. Diaphragms can be purchased already wound on rings ready to be inserted in the meter.

The valve and valve seats are ground and finished the same as in a tin meter.

This type of meter is proved for accuracy in the same manner as the tin meter.

Diaphragm Oil—Use equal parts of the following oils: greasite, pale meter oil and dark cylinder oil.

Allow diaphragms to soak in the oil thoroughly; then wipe off the excess oil before placing the diaphragms in the meter.

This combination of oils can be used on any standard make of tin or iron meters.

Standard Meter Provers—The meter prover is the standard instrument by which the proof of a meter is ascertained. All meter provers should be calibrated by means of a cubic foot bottle which has been standardized by the Bureau of Standards at Washington, D. C.

Fig. 183— STANDARD METER PROVER

The meter prover consists of a tank containing water in which is suspended a bell or holder having a supporting chain going over a large balance wheel. At the end of this chain is a weight holder with weights to give the desired gas pressure inside the bell. To the axis of the balance wheel is attached an involute with a counterpoise weight, the purpose of which is to maintain a uniform pressure at all points of travel of the bell. The wheel, chain, involute and weights are supported by a framework consisting of three columns and a triangular bridge across the top of the columns. The bases of the columns are screwed to sockets in the top of the tank.

The bell is guided by three rollers at the bottom and three at the top of the bell.

On the front of the bell is a scale properly graduated in cubic feet and fractions thereof by means of which is ascertained the exact amount of gas or air passed through a meter during its test.

Fig. 184—SMALL PORTABLE PROVER

On the front of the body is a channel having at its top a valve and two cocks—right and left-hand. A hose is attached to either one of the cocks, as desired. On the outer end of this hose is a coupling for attaching to the meters to be tested. The connection to the meters is made by using intermediate reducers or increasers called inlet connections, except for one size which the hose coupling will fit, usually the ten-light meter.

Two thermometers are provided for each prover—one to give the temperature of the water and the other that of the air. A six-inch siphon gauge is also furnished to give the pressure under which the prover is being operated.

These provers are usually constructed of galvanized iron throughout, either japanned or plainly painted. They are also made with brass tank, or body, japanned, and polished copper bell, this latter form being preferred by many on account of its durability.

The regular sizes are 2-foot, 5-foot, 10-foot and 20-foot capacity.

Cubic Foot Bottle—This instrument is the basis of all gas measurement. The correctness of any gas measur-

ing device is, in its final analysis, determined by the cubic foot bottle.

It is standardized by the Bureau of Standards at Washington, D. C., and its accuracy is beyond dispute.

The principle that it works on is simple enough namely, a volume of one cubic foot of gas being

Fig. 186—PORTABLE CUBIC FOOT BOTTLE

displaced by a volume of one cubic foot of water.

As can be seen from the illustration, there is a cabinet containing and supporting the cubic foot bottle with its system of piping and tank. The bottle, as the copper receptacle in the center of the cabinet is called, has a capacity of

Fig. 186
CUBIC FOOT BOTTLE FOR TESTING PROVERS

one cubic foot. At its top and bottom are gauge glasses with pointers.

The operation is as follows: The lower tank is filled with water and this water is pumped to the upper tank. All temperatures of water, room and instrument to be tested are equalized. Then close all cocks, open the vent above the bottle and open the cocks that admit the water from the top tank to the bottom of the bottle and allow the water to come to the pointer on the lower gauge glass. At this instant close the lower cock. Then close the vent and open the cocks in the line of piping leading to the article being tested. Then reopen the cock admitting water to the bottle. Allow the water to fill the bottle and to come to the pointer on the upper gauge glass. Close the water cock and the piping cock. Then one cubic foot of air has been delivered. Next open the vent and the cock admitting water to the lower tank and allow the water to drain out of the bottle. Next pump the water from the lower tank to the upper. Then repeat the method of procedure of operation of the bottle if successive cubic feet are desired. Extreme care must be exercised to always

have temperatures exact and unvarying. In some instances the operation must be conducted in a room in which the air is saturated with aqueous vapor.

Correction of Erratic Meters (BY F. H. OLIPHANT)—A **fast** meter is one which registers too many cubic feet and a **slow** meter is one which registers too few cubic feet, as compared with a prover which measures the correct number of cubic feet and which is the standard to which all meters are compared.

The multipliers in the following tables are all less than one for **fast** meters and greater than one for **slow** meters.

A meter on which the dial shows 10.5 cubic feet when the prover shows 10 cubic feet is called five per cent. **fast** and must be multiplied by .952 to reduce the quantity to standard. A meter on which the dial shows 9.5 cubic feet when the prover shows 10 cubic feet is called five per cent **slow** and must be multiplied by 1.053 to bring it up to the standard.

Because the dial of many meters cannot be read as accurately as the scale on the prover it is preferred in some cases to pass the air or gas through meter and prover until the meter registers 10 cubic feet, then shutting off and reading the prover scale. For this use a second table is introduced, which however is consistent with the first. This method simplifies the computation for the multiplier, which shows directly from the prover scale, being one-tenth the value of the prover scale reading.

The correction factor or multiplier to correct erratic meters is determined by the following formula:

$$\text{Multiplier} = \frac{\text{Prover Reading}}{\text{Meter Reading}}$$

EXAMPLE:—Say the reading of a meter is 10.0 while the prover reads 12.5, then the multiplier $\frac{12.5}{10} = 1.25$. Or say

the prover scale reads 8 when the meter reads 10. Then $\frac{8}{10} =$ .8 is the multiplier.

The formula for determining the percentage that a meter is fast is as follows: $\frac{(\text{Meter Reading} - \text{Prover Reading})}{\text{Prover Reading}} \times 100 =$ percentage error fast.

EXAMPLE:—Say a meter registers 10 cu.ft. while the prover shows 8 $\frac{(10-8) \times 100}{8} = \frac{200}{8} = 25$ per cent error fast.

The formula for determining the percentage error of a slow meter is as follows:

$\frac{(\text{Prover Reading} - \text{Meter Reading})}{\text{Prover Reading}} \times 100 =$ percentage error slow.

EXAMPLE:—Say a slow meter registering 10 showed 12.5 cu. ft. on the prover, then $\frac{(12.5-10) \times 100}{12.5} = \frac{250}{12.5} = 20$ per cent error slow.

The multipliers for slow and fast meters are determined by the following formulas. Multipliers for meters that are slow $= \frac{100}{100 - \text{per cent slow.}}$ Multipliers for meters that are fast $= \frac{100}{100 + \text{per cent fast.}}$

EXAMPLE:—Suppose a meter is said to be 20 per cent. slow, how is the correction factor or multiplier to be determined? In this case the multiplier $= \frac{100}{100-20} = \frac{100}{80} =$ 1.25.

On the other hand, suppose a meter is reported 25 per cent fast. Here the multiplier $= \frac{100}{100+125} = \frac{100}{125} = .80.$

EXAMPLES:—Suppose 10 cubic feet in a meter showed only 7.5 cubic feet in the prover, the meter is 33.33 per cent

Table No. 82—Table Giving Multipliers for Correction of Erratic Register of Meters Slow and Fast

Meter Reading Cu. Ft.	Slow Meters			Fast Meters		
	Prover Reading Cu. Ft.	Percentage of Variation (Prover being Standard)	Multipliers to Correct Slow Meters	Prover Reading Cu. Ft.	Percentage of Variation (Prover being Stand'd)	Multipliers to Correct Fast Meters
10	13.7	27.00	1.37	10.0	0.00	1.00
10	13.6	26.47	1.36	9.9	1.01	.99
10	13.5	25.93	1.35	9.8	2.04	.98
10	13.4	25.37	1.34	9.7	3.09	.97
10	13.3	24.81	1.33	9.6	4.17	.96
10	13.2	24.24	1.32	9.5	5.26	.95
10	13.1	23.66	1.31	9.4	6.38	.94
10	13.0	23.08	1.30	9.3	7.53	.93
10	12.9	22.48	1.29	9.2	8.70	.92
10	12.8	21.88	1.28	9.1	9.89	.91
10	12.7	21.26	1.27	9.0	11.11	.90
10	12.6	20.63	1.26	8.9	12.36	.89
10	12.5	20.00	1.25	8.8	13.63	.88
10	12.4	19.35	1.24	8.7	14.94	.87
10	12.3	18.70	1.23	8.6	16.28	.86
10	12.2	18.03	1.22	8.5	17.65	.85
10	12.1	17.35	1.21	8.4	19.05	.84
10	12.0	16.67	1.20	8.3	20.48	.83
10	11.9	15.97	1.19	8.2	21.95	.82
10	11.8	15.26	1.18	8.1	23.46	.81
10	11.7	14.53	1.17	8.0	25.00	.80
10	11.6	13.80	1.16	7.9	26.58	.79
10	11.5	13.04	1.15	7.8	28.20	.78
10	11.4	12.28	1.14	7.7	29.87	.77
10	11.3	11.50	1.13	7.6	31.58	.76
10	11.2	10.71	1.12	7.5	33.33	.75
10	11.1	9.91	1.11	7.4	35.13	.74
10	11.0	9.09	1.10	7.3	37.00	.73
10	10.9	8.26	1.09	7.2	38.88	.72
10	10.8	7.41	1.08	7.1	40.84	.71
10	10.7	6.54	1.07	7.0	42.86	.70
10	10.6	5.66	1.06	6.9	44.93	.69
10	10.5	4.76	1.05	6.8	47.06	.68
10	10.4	3.85	1.04	6.7	49.26	.67
10	10.3	2.91	1.03	6.6	51.51	.66
10	10.2	1.96	1.02	6.5	53.85	.65
10	10.1	0.99	1.01	6.4	56.25	.64
10	10.0	0.00	1.00	6.3	58.73	.63

fast. In the table opposite 7.5, multiplier .75 is found. Say a meter in use recorded 42,250 cubic feet when disconnected and was found to be 33.33 per cent. fast, then 42,250 × .75 = 31,687.5 cubic feet, which is the corrected quantity. On the other hand, if a meter recording 10 cubic feet gave 11.5 cubic feet in the prover, the meter is 13.04 per cent. **slow,** and in the table opposite 11.5 cubic feet a multiplier of 1.15 is recorded. If the meter registered 42,250 cubic feet when disconnected, then 42,250 × 1.15 = 48,587.5 cubic feet is the correct quantity. It will be observed that the multiplier for correcting erratic meters is the quantity recorded by the prover with the decimal point moved one figure to the left. Then if the prover shows 11.5 cubic feet and the meter 10 cubic feet, the correcting multiplier is 1.15. On the other hand, if the prover shows 7.5 cubic feet and the meter 10, the correcting multiplier is .75. If the prover should show 10.125 and the meter 10 cubic feet, the multiplier will be 1.0125, etc. It is much more direct to use the multiplier than reduce the percentages to get the corrected quantity from an erratic meter.

Fig. 187—A DOMESTIC GAS METER

PART FOURTEEN

DOMESTIC CONSUMPTION OF GAS

High Gas Bills—When a consumer considers his gas bill too high, he should test the house piping for leaks before complaining to the gas company. This is very easily done by turning out all fires and lights, watching the small dial on the meter for at least fifteen minutes. If the hand on this dial moves it indicates leakage in the house piping.

TABLE No. 83

If small dial registers in 15 minutes	Cubic Feet per month leakage	Loss per month with gas at 30c. per 1000 cubic feet
1 cu. ft.	2,880	$0.86
2 "	5,760	1.73
3 "	8,640	2.59
4 "	11,520	3.46
5 "	14,400	4.32

The small hand or any other hand on the dial will not revolve and register gas unless there is gas passing through the meter.

According to S. S. Wyer (see Fig. No. 89), about 16 per cent of the volume of gas actually delivered to the domestic consumer is wasted through leakage on the premises and about 36 per cent through loss in heat energy at the burners. The remainder, or about 47 per cent represents the percentage of the volume from which the consumer derives full benefit in heat units or energy. In other words, in the average gas bill of any amount—for instance, in a bill for 100,000 cu. ft. of gas for one month, only the number of heat units in 47,000 cu. ft. of gas are actually used, while the amount of leakage is 16,000 cu. ft.

FUEL
Small Part of Total Meal Cost

The following comparisons are based on retail market prices of foods in Columbus, Ohio, June, 1917, with natural gas computed at $1.00 net per "1000" cu. ft. Costs in cents are given opposite respective items. Relative per cent represented by each, of the total meal cost, is shown by 100 per cent diagram at each side.

The tests were made with an ordinary natural gas range, using natural gas at 5 oz. pressure, with long flames; if lower pressures-approximately 1 oz. with properly directed short flames, about 3-4 inches long-had been used, the gas consumption would have been halved. With $6.50 soft coal, 27c gasoline, 15c coal oil, or 3c electricity—which makes these more expensive than $1.00 natural gas—the cost of fuel for cooking is still a small part of the total meal cost.

DEPARTMENT OF HOME ECONOMICS

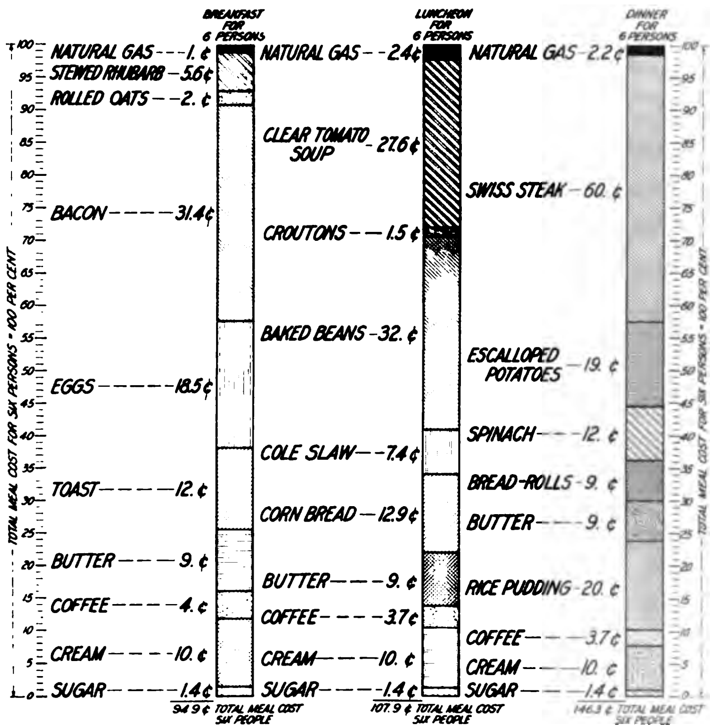


Fig. 188

Fig. 189—GAS ROASTING RANGE

The yellow flame in a stove burner represents a waste of gas and helps to increase the gas bills. There are less heat units in a yellow than in a blue flame. All flames should burn with a blue color tinged with red.

In cooking it is not necessary to leave a burner turned on full head with the flames burning around the sides of a kettle or spider. It is a waste of gas. When through cooking turn off the gas.

Likewise with heating stoves, do not open the doors and windows when the temperature of the room becomes too high. Turn down the gas instead.

The consumer should consider the use of gas the same as he would the use of coal. If he were obliged to purchase gas in quantities the same as he purchases coal or other fuel, and could from time to time watch the diminishing supply, he would naturally be more economical in its use and less likely to think his gas bills too high.

Is it not surprising that the consumer should complain? The complaint is made to the gas company as they are the only ones to benefit financially from the sale of the gas, but what control has the gas company over the waste of gas on the consumers premises? They have no more control over the use of gas in one's home than the grocer has over the groceries he sells. One may purchase a peck of potatoes and waste one-half in the paring and of course never think of complaining to the grocer.

It would be far better for the gas company were the consumers to use the gas with reasonable care and economy. It would lessen the individual gas bills, create personal workers for new consumers and naturally increase the sale of gas by increasing the number of consumers.

Again, if all leakage in the house piping were stopped it would remove a great liability due to the possibility of explosion. Whenever an explosion occurs it invariably means a law-suit and often takes years for the courts

Fig. 190—GAS RANGES USED IN THE PENNSYLVANIA HOTEL, NEW YORK CITY. MANUFACTURED GAS IS USED IN THIS RANGE BUT NATURAL GAS CAN BE USED IN A RANGE OF THIS SIZE

WHERE HAS MY YEAR'S INCOME GONE?

Classifications showing how various annual incomes are spent, taken from the family budget studies of Dr. Ellen H. Richards, of the Massachusetts Institute of Technology, emphasizing the great importance of the food problem. The Public Utility details were taken from page 32 of Wyer's Regulation, Valuation and Depreciation of Public Utilities.

PREPARED BY
DEPARTMENT OF HOME ECONOMICS
THE OHIO STATE UNIVERSITY

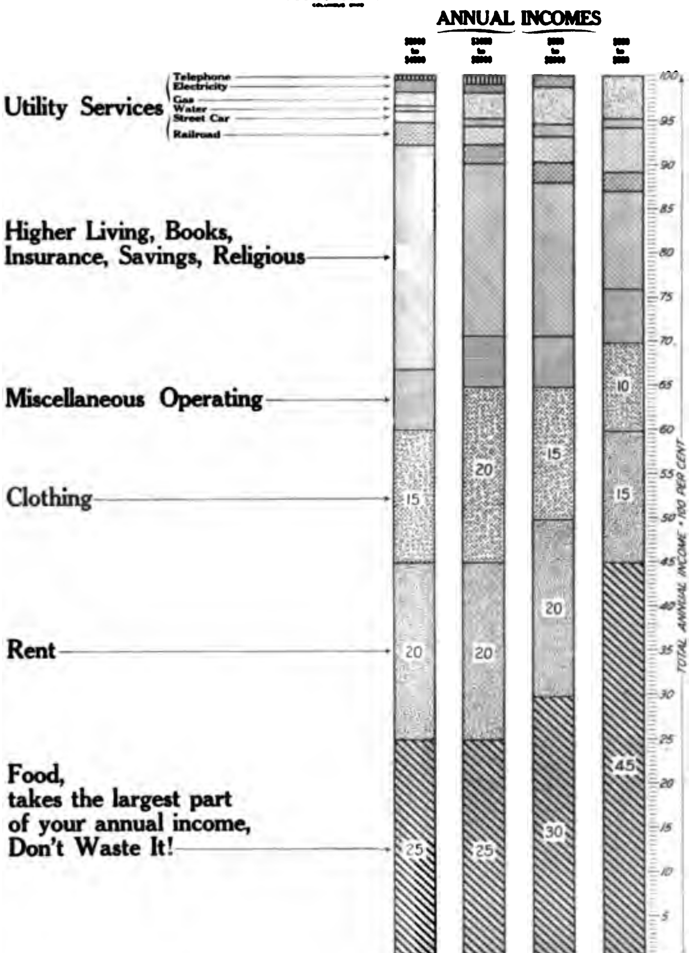


Fig. 191

RELATIVE COST
VARIOUS FUELS FOR COOKING DINNER

Consisting of steak, escalloped potatoes, spinach, bread, butter, rice pudding, coffee, cream, sugar, with portions for six people. The fuel costs were taken as follows: Natural Gas, $1.00 per "1000 cu. feet," Soft Coal, $6.50 per ton, delivered in house; Gasoline, 27c per gallon; Coal Oil, 15c per gallon; Electricity, 3c per K. W. hour The figures in cents indicate the total fuel cost per meal for six persons.

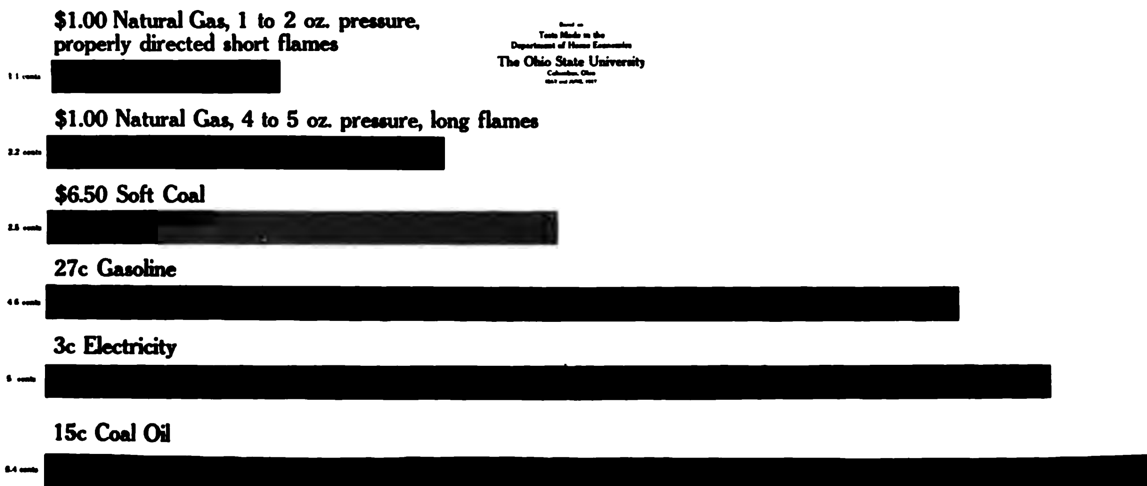


Fig. 192

to determine whether the leak was on the outside or the inside of the house.

If a consumer would do everything in his power to secure an 80 or 90 per cent efficiency in the use of gas, he would have little reason to complain of high gas bills and a great step toward the conservation of our gas resources would be taken.

Proper Color of Flame in Stove Burners—The proper color of the flame in burners should be blue tinged with red.

It is quite common for the burners and mixers to become dirty and then the gas will not properly mix with air. This condition causes a yellow flame.

When this condition exists the burners and mixers should be taken apart and washed clean with hot soap and water, and the mixer should be readjusted till the proper color of flame is obtained.

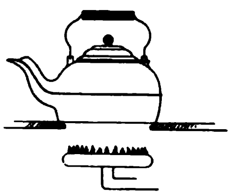


Fig. 193

Fig. 193—A low flame requires more time to boil water, but by raising the burner a most economical fire can be maintained. Pressure ½ ounce.

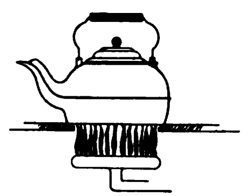


Fig. 194

Fig. 194—The proper size flame for the average gas range. Pressure 2 ounces. Height of flame, 4 inches.

Fig. 195

Fig. 195—Shows gas being wasted. Pressure 5 ounces. Height of flame 10½ inches (measured without kettle over stove hole).

Fig. 196—CHART SHOWING DECREASING PRICE OF GAS IN LOS ANGELES, CAL., TOGETHER WITH THE INCREASE OF NUMBER OF B. T. U. PER CU. FT.

Courtesy of the Board of Public Utilities of the City of Los Angeles, California.

Gas Range Burner Tests—The following tests were made on a modern gas range burner by boiling eight pounds of water with different color flames or mixer adjustments and at different pressures. Temperature of the water at the start of each test was 70 deg. fahr. and at the completion 206 deg. fahr. or boiling point. Pressures were taken at the burner.

TABLE No. 84

WITH YELLOW FLAME

Test No.	Height of flame at center of burner	Pressure in oz.	Time required	Cubic feet of gas burned
1	4 inches	2	20 min.	3.0
2	6½ "	3	17¼ "	3.2
3	8½ "	4	20 "	4.3
4	10½ "	5	21 "	5.

TABLE No. 85

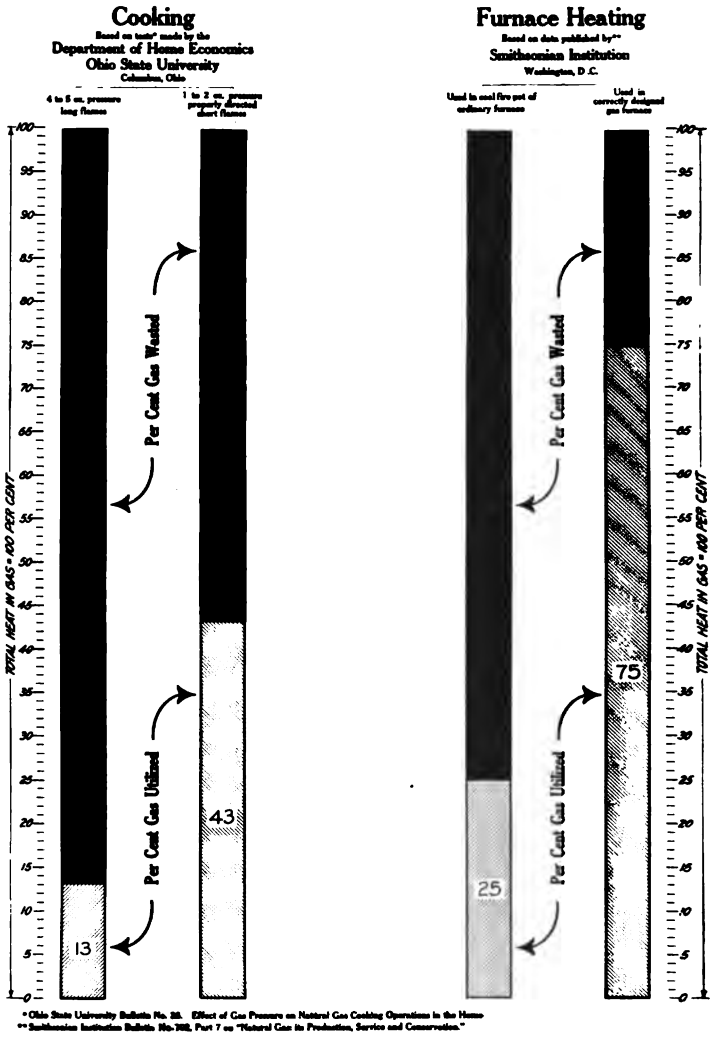
WITH BLUE FLAME

Test No.	Height of flame at center of burner	Pressure in oz.	Time required	Cubic feet of gas
5	4 inches	2	19½ min.	2.8
6	6½ "	3	16½ "	3.
7	8½ "	4	15 "	3.1
8	10½ "	5	14 "	3.4

From the foregoing tests it is shown that the most economical use of natural gas is with the 2-ounce pressure and the blue flame.

Lights—Often the mixer and the screen in the burner will become clogged with dust. By removing the mantle the dust can be blown out with one's breath. The screen in the cap directly under the mantle can be removed or blown out. Clean the pin hole through which the gas enters the

Home Wastes of Natural Gas



* Ohio State University Bulletin No. 28. Effect of Gas Pressure on Natural Gas Cooking Operations in the Home

** Smithsonian Institution Bulletin No. 102, Part 7 on "Natural Gas its Production, Service and Conservation."

Fig. 137

mixer. A hat pin will be found most convenient for this. Do not increase the size of the hole unless the amount of gas is too small to give a full sized blue flame.

House Heating Furnace Tests—An investigation conducted by Samuel S. Wyer for the Ohio Fuel Supply Company in 1912, developed the following information:

Fuel and Furnace	Cost of Fuel Delivered	Heat Units From $1.00 Worth of Fuel
Natural Gas, Special Furnace	$ .30 per cu. ft.	2,023,000
Natural Gas, Ordinary Furnace	.30 per cu. ft.	1,109,000
Coke, Coal Furnace	5.50 per ton	867,000
Nut Coal, Coal Furnace	3.25 per ton	987,000

It should be noted that with gas the fuel consumption can be stopped instantly, whereas with solid fuel the fire must be allowed to burn out.

Imperfect Combustion of Natural Gas in Stoves—No account is taken in the foregoing of the imperfect combustion of gas, either natural or artificial, in poorly constructed gas stoves. The danger in such cases from either gas is great, and not only should stoves be well constructed so that perfect combustion takes place, but every stove should be equipped with a vent connected to the house chimney to take away the products of combustion. If this is not done bad effects may develop, due principally to the generation of small proportions of carbon monoxide. The public is kept more or less aware of the fatalities produced by the imperfect combustion of gas in stoves by frequent citations of such accidents in the daily newspapers.

Removal of Products of Combustion of Natural Gas from Rooms—Natural gas, when burned with sufficient oxygen for complete combustion, forms carbon dioxide and water vapor. Each cubic foot of natural gas burned produces a little over one cubic foot of carbon dioxide and a little more than two cubic feet of water vapor. Carbon dioxide is an

irrespirable gas and should not be allowed to accumulate in a room. Water vapor also should be removed because, in sufficient proportions, it has a depressing effect and tends to make the walls, ceiling, curtains, and other objects in a room dirty.

The only way to remove these two gases is by means of a vent or pipe leading from the stove to a house chimney.

It is Absurd for any Manufacturer of Stoves to Claim that these two Gases are Practically Absorbed, Eliminated or Burned in the Stove in any Manner Whatever.

In tests made in the Department of Home Economics of the Ohio State University to determine the relative costs of various fuels for cooking, the following startling relationships were found:

Natural gas at $1.12 per M. is equivalent to coal at $6.50 per ton.
Natural gas at $2.00 per M. is equivalent to gasoline at 27 cents per gallon.
Natural gas at $2.20 per M. is equivalent to electricity at 3 cents per kilowatt.
Natural gas at $2.40 per M. is equivalent to coal oil at 15 cents per gallon.

Suggestions for Domestic Consumers—Do not look for a leak with a lighted match or candle. Upon first discovery of a leak open all doors and windows.

A leak in house piping can be temporarily stopped by covering the opening with soap and a bandage. If this is resorted to, permanent repairs should be made as quickly as possible.

Sweating on walls in a residence is caused by bad drafts, open top stove or lack of chimney connection. It is more apt to occur in winter when the houses are kept closed.

There is about ten per cent more moisture in burnt fumes from manufactured gas than from natural gas.

Keep the damper in the stove pipe partially closed according to the amount of fire in the stove. Natural gas does not require a great amount of draft, but what little it does require must be perfect.

Do not use rubber tubing for connecting gas to heating stoves, hot plates or cook stoves, and for light connections it is allowable only with perfect connections at the burner and the hose cock. When rubber tubing is used for lights use the valve at the gas fixture. Flexible metallic tubing is safer than rubber tubing. A great many asphyxiations and fires have been directly accounted for by rubber hose connections.

Heating or cook stoves should not be used without a chimney connection to carry off the burnt gases.

The effect of burnt gases on the room itself is a condensation of the moisture on the walls or windows, often causing the paper to drop from the walls.

Gas stoves should be placed at a safe distance from the wall, with a sheet of metal underneath.

Domestic consumers should learn to read their own meter and thus be able to verify the correctness of their monthly gas bill. This will also give an opportunity of determining how much gas any particular stove will burn an hour.

Cooking and Heating with Natural Gas When Pressure is Low or a Shortage of Gas Exists—The majority of consumers consider that when the gas pressure is low they are being cheated by the gas company and that a refund should be given. Actually, however, the gas company is the loser. If it had more gas to sell, it would be receiving greater returns during the period of shortage. No gas company desires to have a shortage and invariably does everything in its power to forestall anything of this nature. The efforts put forth by gas companies in this direction are seldom known and rarely appreciated by the consumer. A shortage has never taken place but that the gas company could have sold more gas during the period than it actually had to sell.

The consumer may state that "the gas is low" and that the gas obtained by him is "no good" and has air in it. The

first statement is justifiable in case of a shortage, but the latter two are unreasonable though they must be answered with all due politeness and consideration.

The writer has never known of an instance where air has been "pumped" into a gas line, either at high or low pressure, to increase the meter bills. The fact that it is a most dangerous practice is too well known to natural gas men.

Without question, the consumer is getting the same quality of gas, during the shortage, as when the pressure is normal.

It has been proven that with low pressure during a gas shortage (as, for instance, one or two ounces) more actual benefit is received by the consumer per cubic foot of gas than when the pressure is high or normal.

When the fire in a cook stove actually blows or roars, it is a true indication that a full benefit of the heat units in the gas is not being taken advantage of and considerable waste exists.

In a heating stove practically the same number of heat units per cubic foot of gas are obtained when the pressure is low as when the pressure is high or normal.

The consumer can state honestly that he is not getting enough gas for his wants, but as to the quality of the gas being different or poor, this is a mistaken idea.

It should be borne in mind by the consumer that during exceptionally cold weather, when shortages are likely to take place, natural gas is a luxury given us by nature and is not simply a case of "put on more coal" to increase the supply.

HOW TO COOK WITH LOW-PRESSURE NATURAL GAS*

Sec. 1—"Properly Directed Flames Necessary—In burning gas for cooking three distinct steps are necessary: †

(a) The gas must be properly burned; that is, it must be properly mixed with air so as to burn with a pale blue non-luminous flame. A luminous flame will be wasteful and will deposit soot on the cooking vessel.

(b) The flame must be properly directed; that is, the tip of the flame must come close to the cooking vessel. If the flame is too short to reach the cooking vessel, or is blown to one side by a strong draft of air, gas will be wasted, a longer time will be required, and if the flame tip is too far away it may be impossible to cook, although the short improperly directed flames may be kept burning a long time.

(c) The heat generated by the burning gas must be delivered through the cooking vessel walls and into the food. Hence, thin vessels and grid or open stove tops are necessary for good service. Natural gas should never be used under a solid stove top because it is always wasteful and under low pressure conditions may make cooking impossible.

Sec. 2—Wrong Burner and Vessel Position—Fig. 198 shows what happens when low pressure natural gas is burned in the usual natural gas stove. The cooking vessel is so far away that the short flames cannot reach it. This results in waste of gas, longer time to cook, and in some cases impossibility to cook at all, even though the gas may be burned for a long time.

Sec. 3—Correct Burner and Vessel Position—Merely lowering the cooking vessel or raising the burner, as shown

* Prepared by Samuel S. Wyer, Consulting Engineer, Columbus, Ohio, Oct. 24, 1919.

† For further discussion of gas use, see Bulletins of the Department Home of Economics, Ohio State University, Columbus, Ohio, on:

"Effect of Gas Pressure on Natural Gas Cooking Operations in the Home."

"Kitchen Tests of Relative Costs of Five Fuels for Cooking." Reprinted October, 1918.

below, will result in satisfactory cooking, in the usual length of time with same low pressure, same stove and same burner. In fact, using properly directed short flames at low pressure, as shown below, will actually use less than one-half of the gas required with the usual high pressure and resulting long flames.

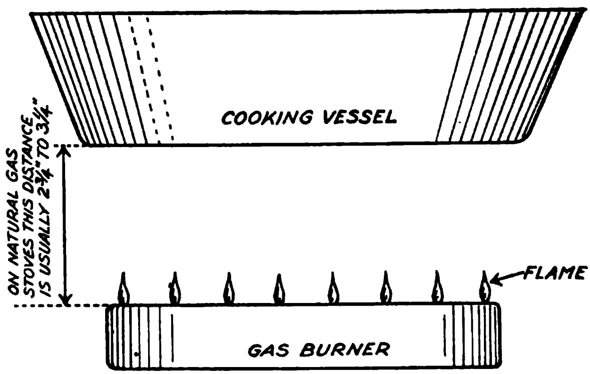


Fig. 198

Sec. 4—How to Get Vessel and Burner in Correct Position—For permanent service in purchasing new stoves, get either an artificial gas stove or a natural gas stove with burners properly raised for short flame service. Old stoves worth remodeling may be changed by:

(a) Raising the burner, burner supports, and manifold —that is, pipe into which gas burner cocks are screwed.

(b) New burner castings of proper height for short flames may be secured for some stoves.

(c) Cementing casting on top of existing burners so as to bring the burner to the proper height.

(d) Depressed grid tops to bring the vessel support down to the low burners.

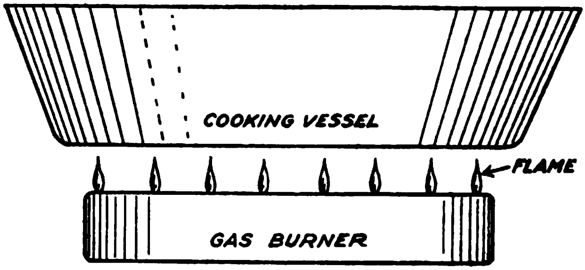


Fig. 199

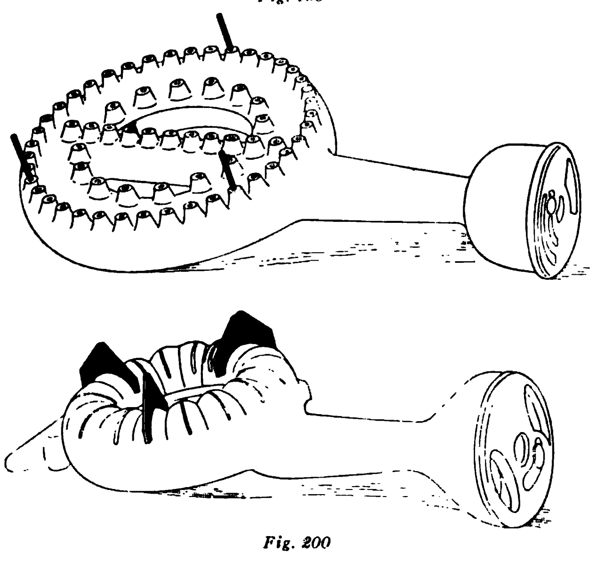


Fig. 200

Closed tops must never be used and in all cases where burners are raised, grid or open tops must be used with the short flames.

A larger sized spud opening—that is, the small opening immediately in front of the gas cock through which the gas passes into the mixer—should be used with low pressure service Some stoves have adjustable spuds; others must either have new spuds or have the old small openings reamed larger.

If the pressure in the gas mains is too high, the more efficient short-flame low-pressure conditions can still be maintained by merely partially opening the gas cock. Never let the flame lick up along the side of the vessel.

Baker burners need not be raised, because the heat from the burning gas is already inside of the chamber to be heated. The spud and mixer must, however, be properly adjusted so as to get a pale blue non-luminous flame.

As a temporary means, remove the stove top and on drilled burners insert three wire nails and on slotted burners, three pieces of sheet-iron, for supporting the cooking vessel as shown in Fig. 200, so that the tip of the short, low-pressure flame comes close to the vessel bottom.

Dirty gas burners frequently prevent proper cooking operations."

Comparison of Domestic Meter Bills by the Consumer— Distributing companies commonly receive complaints from patrons that their friends, neighbors or acquaintances with smaller homes, fewer people in the family, and with extravagant appliances, have smaller bills.

First, make sure that the meter is accurate, either by looking up the record and learning that the meter in question has lately been tested, or by making a special test. Then carefully and politely take up the comparison of grocery or other household bills. It will be found that they will not foot up the same. The number of rooms in a house has as little to do with the gas bill as the number of people in the family has to do with the grocery bill. No two families are alike with regard to their home wants and requirements.

It might be added that it is just as reasonable for the gas man to sell gas by the stove or flat rate as it is for the grocery man to contract to supply groceries for a home by the number of persons in it.

Water Condensation from Burnt Gases (By PROFESSOR HAWORTH) — "When burned, one volume of methane (the

TABLE No. 86—COMPARATIVE GAS STATISTICS OF AMERICAN CITIES

City	Approximate Population Served	C. F. Annual Sales in millions	Max. Days Send Out	Consumers and Meters	No. of Co's.	Kind of Gas	Heat Units	Process	Rate per M. Ft.
*New York	5,300,000	56,184	95,331,600	1,510,173	18	Artificial	707	Coal—Lowe	$ .80 to $1.00
Chicago	2,200,000	21,693	78,890,000	689,983	2	Artificial	600	Lowe	.80
Philadelphia	1,767,000	12,643	....	406,776	2	Artificial	...	Coal—Lowe	1.00
Boston	730,600	7,150	21,895,000	201,030	3	Artificial	600	Coal—Lowe	.80
St. Louis	750,000	.....	20,079,000	160,206	1	Artificial	610	Coal—Lowe	.85
*Pittsburgh	579,000	.....	....	270,298	4	Natural	...	Natural	.28½ to .32
†Los Angeles	625,000	6,629	39,016,740	186,482	3	Mixed and Nat.	825–900	Oil and Nat.	.68 and .64½
Cleveland	765,000	.....	....	290,000	1	Natural	...	Natural	.33
Baltimore	700,000	4,487	16,127,000	126,550	1	Artificial	600	Lowe	.85
New Orleans	375,000	1,335	6,016,000	45,710	1	Artificial	600	Lowe	1.19
St. Paul	262,000	1,463	....	43,827	2	Artificial	610	Lowe	1.05
Minneapolis	363,000	2,655	9,166,000	83,162	1	Artificial	600	Coal—Lowe	.92
Washington	331,000	2,903	12,827,404	74,608	2	Artificial	637	Coal—Lowe	.75 to .95
San Francisco	560,000	4,595	20,071,000	123,272	1	Artificial	606	Oil	.85
Detroit	750,000	8,000	....	173,000	1	Artificial	...	Coal—Lowe	.85
Newark	637,000	4,553	....	168,642	1	Artificial	...	Coal—Lowe	.90
Kansas City	312,000	5,277	....	69,823	1	Natural	...	Natural	.30
Seattle	348,000	1,078	3,500,000	46,731	1	Artificial	...	Coal—Lowe	1.25
Portland	295,000	1,308	5,399,000	46,525	1	Artificial	570	Lowe	1.00
Denver	260,000	1,269	4,490,800	43,199	1	Artificial	615	Coal—Lowe	.95
Buffalo	468,000	.....	....	96,428	3	Natural	...	Natural	.32 to .35
Cincinnati	410,000	.....	....	114,498	1	Natural	...	Natural	.40
Louisville	264,000	.....	....	....	1	Natural	...	Natural	.40
Milwaukee	436,000	3,709	....	99,200	1	Artificial	600–650	Coal—Lowe	.75
Indianapolis	250,000	2,390	9,543,000	59,107	1	Artificial	...	Coke—Water	.55

NOTE—*Value of gas sold by four companies for year—$19,870,991.03.
†One company serves natural gas at 64.5c and the other two companies a mixture of natural and manufactured gas.

main constituent of natural gas) unites with two volumes of oxygen, which is equivalent to ten volumes of air.

The products of combustion are two volumes of water vapor and one volume of carbon dioxide. The production of water vapor becomes apparent in the combustion of natural gas, the water vapor condensing and collecting on any cold object near the burning gas. This gives rise to the popular belief that the gas as it comes in the pipes is wet or loaded with water. A simple calculation will show us the remarkably large amount of water produced in the burning of 1000 cubic feet of methane.

Each 1000 cubic feet of methane produces on combustion twice its own volume or 2000 cubic feet of water vapor. This weighs 100.13 lb. and is equal to approximately 12 U. S. gallons of liquid water. Now if we have a natural gas containing ninety-five per cent of pure methane, it would give ninety-five per cent as much water per 1000 cubic feet, that is 95 lb. or 11.4 gallons.

This shows that the production of a large quantity of water is an inevitable accompaniment of the combustion of natural gas, and it is no evidence of a good or a bad quality of gas itself, excepting that the quantity of water thus produced increases as the percentage of methane in the gas increases. It therefore should be considered a sign of good quality instead of bad. The heat of combustion of methane is 1003 B. t. u. per cubic foot of gas."

Incandescent Light Mantles—The original research work in the invention of the incandescent light mantle was begun by Carl Auer von Welsbach in 1880 at the Bunsen Laboratory at the University of Heidelberg.

Not until 1890 did this young man bring the invention to a successful standard. The preparation consisted of 1 per cent cerium and 99 per cent thorium. The cerium is responsible for the high luminous effect.

Artificial fibre, cotton, and ramie thread are used to support the coating of cerium and thorium. The cotton and ramie thread are hollow while the artificial fibre is like a solid rod. The shrinkage of mantles is generally due to the cotton or ramie thread collapsing after burning.

Before using, the mantles must be burnt off, leaving the "ash" of the original make-up, this ash being the real light producer.

GAS RATES

The following gas rates are now (1919) in effect in various towns and cities, in the different states given. No attempt is made to publish all the rates charged in all towns and cities, but a sufficient number of gas rates is given to present a comprehensive idea of what prices are being charged in different states, and to act as a guide to new companies establishing rates.

Other gas rates will be found in Mr. I. C. White's article, in Part One. See pages 66 and 67.

ARKANSAS

LITTLE ROCK GAS & FUEL CO., LITTLE ROCK, ARK.

RATES FOR GAS—Based on amount of gas used in one month through one meter. If not paid when due the company reserves the right to discontinue the service without further notice.

For the first 50,000 cubic feet, 45 cents per 1,000 cubic feet.
For the next 50,000 cubic feet, 40 cents per 1,000 cubic feet.
For the next 50,000 cubic feet, 35 cents per 1,000 cubic feet.
For the next 50,000 cubic feet, 30 cents per 1,000 cubic feet.
For all over 200,000 cubic feet, 20 cents per 1,000 cubic feet.

A minimum charge of $1.00 per month will be made.

CALIFORNIA

VALLEY NATURAL GAS COMPANY, BAKERSFIELD, CALIFORNIA

SCHEDULE OF RATES

(A)

Domestic Service	Gross	Net
Per 1,000 cubic feet	60c	50c

(B)

Gas Engine Service		
First 150,000 cubic feet per month	30c	25c
Next 150,000 cubic feet per month	25c	20c
Over 300,000 cubic feet per month	20c	15c

(C)

Industrial Service	
(a) Midway District	
Per 1,000 cubic feet	9c
(b) Dern District	
Per 1,000 cubic feet	10c

All bills rendered at gross rate. Net rate applies if payment is made on or before 10th of month following purchase.

Application for service only required. No definite contract period.

Industrial service applies to boilers, furnaces, forges, etc., and is subject to discontinuance at any time for protection of domestic or gas engine consumers.

RATES

Company	Per M Cu. Ft.
L. A. Gas & Electric Corp'n (City) Mixed, 815 B. t. u.	$ .68
So. Cal. Gas Co. (City), Mixed, 815 B. t. u.	.68
Economic Gas Co. (City), Natural, 900 B. t. u.	.64½
So. Counties Gas Co. (San Pedro-Wilmington), Natural, 1050 to 1200 B. t. u.	1.25
L. A. Gas & Electric Corp'n (Palms), Mixed, 815 B. t. u.	.68
So. Counties Gas Co. (Westgate), Mixed, 815 B. t. u.	1.00
So. Cal. Gas Co. (Van Nuys-San Fernando Val.), Natural, 1050 B. t. u.	.85
So. Cal. Gas Co. (Shoe-string Strip), Natural, 1050 to 1200 B. t. u.	.85

LOS ANGELES GAS AND ELECTRIC CORPORATION

GAS RATE SCHEDULE, SEPT. 15, 1917

No. 1

TERRITORY:

This schedule applies to Rate District No. 1, which includes the following territory:

That portion of the City of Los Angeles designated as follows:

a.—Original City as Incorporated in 1850.
b.—Extension of June 1, 1869.
c.—City of Hollywood Addition south of the southern boundary extension of Sec. 4, Twp. 1 S., R. 14 W., S. B. B. & M.
d.—Colegrove Addition.
e.—Western Addition.
f.—University Addition.
g.—Southern Addition.
h.—Shoestring Addition North of the Center Line of Slauson Avenue.

CHARACTER OF SERVICE:

This schedule applies to sale of "815 B. t. u." gas for domestic and commercial service for lighting, cooking, heating, etc.

RATE:

First	5,000 cu. ft. per meter per Mo.	68c per 1000 cu. ft.
Next	5,000 cu. ft. per meter per Mo.	60c per 1000 cu. ft.
Next	15,000 cu. ft. per meter per Mo.	55c per 1000 cu. ft.
Next	25,000 cu. ft. per meter per Mo.	50c per 1000 cu. ft.

All over 50,000 cu. ft. per meter per Mo. 45c per 1000 cu. ft.

MINIMUM BILL:

Minimum Monthly Bill per meter for domestic service for flats and apartments where four (4) or more meters are continuously served in one location and on one service—35c.

Minimum Monthly Bill per meter for domestic and commercial service other than above—50c.

GAS RATE SCHEDULE

No. 2

TERRITORY:

This schedule applies to Rate District No. II, which includes the following territory:

City of Pasadena east of the center line of the Arroyo Seco Wash and south of the center line of Washington Avenue.

CHARACTER OF SERVICE:

This schedule applies to sale of "815 B. t. u." gas for domestic and commercial service for lighting, cooking, heating, etc.

RATE:

First	3,000 cu. ft. per meter per Mo.	75c per 1000 cu. ft.
Next	7,000 cu. ft. per meter per Mo.	65c per 1000 cu. ft.
Next	15,000 cu. ft. per meter per Mo.	55c per 1000 cu. ft.
Next	25,000 cu. ft. per meter per Mo.	50c per 1000 cu. ft.
All over	50,000 cu. ft. per meter per Mo.	45c per 1000 cu. ft.

MINIMUM BILL:

Minimum Monthly Bill per meter for domestic service for flats and apartments where four (4) or more meters are continuously served in one location and on one service—35c.

Minimum Monthly Bill per meter for domestic and commercial service other than above—50c.

GAS RATE SCHEDULE

No. 3

TERRITORY:

This schedule applies to Rate District No. III, which includes the following territory:

That part of the City of Los Angeles designated as follows:

a.—Highland Park Addition.
b.—Arroyo Seco Addition.
c.—Garvanza Addition.
d.—East Hollywood Addition south of San Bernardino Base Line.
e.—City of Hollywood Addition not included in District No. I.
f.—Palms Addition east of N. and S. section line extended between section No. 4 and Sec. No. 5, Twp. 2 S., R. 14 W., S. B. B. & M.
g.—Shoestring Addition north of Manchester Avenue and south of Slauson Avenue.
h.—Bairdstown Addition north of Huntington Drive.

Incorporated territory of:

i.—City of South Pasadena.
j.—City of Alhambra.

CHARACTER OF SERVICE:

This schedule applies to sale of "815 B. t. u." gas for domestic and commercial service for lighting, cooking, heating, etc.

RATE:

First	3,000 cu. ft. per meter per Mo.	80c per 1000 cu. ft.
Next	7,000 cu. ft. per meter per Mo.	70c per 1000 cu. ft.
Next	15,000 cu. ft. per meter per Mo.	60c per 1000 cu. ft.
Next	25,000 cu. ft. per meter per Mo.	50c per 1000 cu. ft.
All over	50,000 cu. ft. per meter per Mo.	45c per 1000 cu. ft.

MINIMUM BILL:

Minimum Monthly Bill per meter for domestic service for flats and apartments where four (4) or more meters are continuously served in one location and on one service—35c.

Minimum Monthly Bill per meter for domestic and commercial service other than above—50c.

GAS RATE SCHEDULE

No. 4

TERRITORY:

This schedule applies to Rate District No. IV, which includes the following territory:

1.—That part of the City of Los Angeles and City of Pasadena not included in Districts No. I, No. II and No. III, served by Los Angeles Gas and Electric Corporation.

2.—Incorporated territory of:
- a.—San Marino.
- b.—San Gabriel.
- c.—Eagle Rock.
- d.—Huntington Park.
- e.—Vernon.
- f.—Watts.
- g.—Inglewood.

3.—All incorporated and unincorporated territory which is served by Los Angeles Gas and Electric Corporation and not included or listed above in Districts Nos. I, II and III.

CHARACTER OF SERVICE:

This schedule applies to sale of "815 B. t. u." gas for domestic and commercial service for lighting, cooking, heating, etc.

RATE:

First	3,000 cu. ft. per meter per Mo.	85c per 1000 cu. ft.
Next	7,000 cu. ft. per meter per Mo.	70c per 1000 cu. ft.
Next	15,000 cu. ft. per meter per Mo.	60c per 1000 cu. ft.
Next	25,000 cu. ft. per meter per Mo.	50c per 1000 cu. ft.
All over	50,000 cu. ft. per meter per Mo.	45c per 1000 cu. ft.

MINIMUM BILL:

Minimum Monthly Bill per meter for domestic service for flats and apartments where four (4) or more meters are continuously served in one location and on one service—35c.

Minimum Monthly Bill per meter for domestic and commercial service other than above—50c.

INDIANA

Natural gas rates have also been increased in Indiana after hearings by the Indiana Public Service Commission for the cities of Muncie, Hartford City, Fairmont and Richmond as follows:

Quantity		Gross Rate	Discount	Net Rate
First	1,000 cu. ft.	80c	10c	70c
Next	1,000 " "	70c	10c	60c
Next	1,000 " "	65c	10c	55c
Next	1,000 " "	60c	10c	50c
Next	1,000 " "	50c	10c	40c
Next	5,000 " "	45c	10c	35c
All over	10,000 " "	30c	10c	30c
Minimum Bill		80c	10c	70c

The above mentioned cities are supplied with natural gas, by The Logan Natural Gas & Fuel Company, and the higher rates, which are willingly granted, clearly indicate the value placed upon it by communities once supplied with natural gas, which because of its depletion were compelled to use artificial gas, until now again supplied with natural gas.

After hearings in each case the Indiana Public Service Commission has also entered orders as below establishing rates for natural gas for the cities mentioned:

MIDDLETOWN—LOGAN COMPANY'S NATURAL GAS

Minimum bill	$1.00	per month
First 2,000 cu. ft.	1.00	per thousand
All over 2,000 " "	.50	" "

NOBLESVILLE AND TIPTON—LOGAN CO'S NATURAL GAS

Minimum bill	$ .75	per month
First 1,000 cu. ft.	.75	per thousand
Next 4,000 " "	.60	" "
Next 20,000 " "	.40	" "
All over 25,000 " "	.30	" "

PORTLAND—INDIANA NATURAL GAS

First 1,000 cu. ft. or any part thereof................$1.00
All over 1,000 cu. ft. at ten cents per one hundred (100) cu. ft.

UNION CITY—INDIANA NATURAL GAS

Minimum bill	$1.00	per month
First 5,000 cu. ft.	$ .75	per thousand
Next 3,000 " "	.55	" "
All over 8,000 " "	.40	" "

It is unfortunate for consumers of natural gas in Indiana that her Public Service Commission has not inaugurated a RISING scale of gas rates increasing with consumption as in Ohio, instead of DECREASING with large and wasteful consumption, and thus tending to insufficient supply in many communities during extreme cold weather.

KANSAS

Neodesha, Kansas	Domestic	35c per 1,000 cu. ft.
	Industrial	15c per 1,000 cu. ft.
Yates Center, Kansas	Domestic	35c per 1,000 cu. ft.
	Industrial	25c per 1,000 cu. ft.
Buffalo, Kansas	Domestic	35c per 1,000 cu. ft.
	Industrial	15c per 1,000 cu. ft.
Burlington, Kansas	Domestic	40c per 1,000 cu. ft.
	Industrial	25c per 1,000 cu. ft.
*Altoona, Kansas	Domestic	45c per 1,000 cu. ft.
	Industrial	35c per 1,000 cu. ft.

LOUISIANA

SHREVEPORT NATURAL GAS COMPANY, INC.

October 1, 1918.

First 100,000 cu. ft. at .15 M less .01 M
If paid within 10 days 14c net per M
Next 100,000 cu. ft. month at .13 M less .01 M
If paid within 10 days 12c net per M
Next 100,000 cu. ft. month at .11 M less .01 M
If paid within 10 days 10c net per M
Next 100,000 cu. ft month at .09 M less .01 M
If paid within 10 days 8c net per M
All in excess of 400,000 cu. ft. month at .08 M less .01 M
If paid within 10 days 7c per net M

Discounts to be allowed only if payment is made within 10 days from date of bill.

SOUTHWESTERN GAS & ELECTRIC CO., SHREVEPORT, LA.

DOMESTIC—25c per thousand cu. ft. less 10 per cent discount.

PUBLIC INSTITUTIONS—20c per thousand cu. ft., less 10 per cent discount.

MANUFACTURING—11c per thousand cu. ft., less 30 per cent. discount.

* This is handled on a per cent. basis—60% and 40% on domestic, and 85% and 15% on industrial.

OHIO

NEW RATES OF THE EAST OHIO GAS COMPANY IN OHIO CITIES

Place	Rate	Gross	Net	Min. Charge	Readiness to Serve Charge
Canton:					
First	5,000 ft. each month.......	48c	45c	90c	...
Next	5,000 " " "	53c	50c	...	...
Next	5,000 " " "	58c	55c	...	...
All over	15,000 " " "	63c	60c	...	...
Canal Dover; Same as Canton......		...	...	90c	...
Cuyahoga Falls; Same as Canton...		...	...	90c	...
East Palestine......................		63c	60c	...	50c
East Youngstown; Same as Canton.		...	...	90c	...
Girard; Same as Canton............		...	...	90c	...
Hubbard..........................		63c	60c	90c	...
Kent; Same as Canton.............		...	...	90c	...
Niles; Same as Canton.............		...	...	90c	...
North Canton; Same as Canton.....		...	...	90c	...
New Philadelphia; Same as Canton.		...	...	...	60c
Massillon; Same as Canton.........		...	...	90c	...
Ravenna; Same as Canton..........		...	...	90c	..
Struthers; Same as Canton.........		...	...	90c	...
Warren; Same as Canton...........		....	...	90c	...

NEW RATES IN EFFECT AT LIMA, ETC.

CLASS 1—DOMESTIC PURPOSES:

WINTER RATES: For the months of November, December, January, February, March, and April:

First	35,000 cu. ft. each month..................	50c per thousand
Next	5,000 " " " "	60c " "
All over	40,000 " " " "	70c " "

SUMMER RATE: For the months of May, June, July, August, September and October:

All gas consumed each month, 50c per thousand cubic feet.

READINESS TO SERVE CHARGE: 35c per month.

CLASS 2—INDUSTRIAL PURPOSES:

For the months of May, June, July, August, September and October:

Classes "A" and "B" as defined in Order No. 34 of the P. U. C. O., 50c per 1,000 cubic feet.

Class "C" as defined in same Order:

50c for first 10,000 cubic feet.

All over 10,000 cubic feet: 40c per thousand.

CRIDERSVILLE: (Same rates as Lima, except No INDUSTRIAL).
COLDWATER:
  CLASS No. 1—DOMESTIC PURPOSES:
    50c per thousand cubic feet. No INDUSTRIAL.
  READINESS TO SERVE CHARGE: 35c.
WAPAKONETA: (Same rates as Lima).
SAINT MARY'S: (Same as Lima).
CELINA: (Same as Lima).
RECOVERY:
  CLASS No. 1—DOMESTIC PURPOSES:
    50c per thousand cubic feet.
  READINESS TO SERVE CHARGE: 35c No INDUSTRIAL..

OKLAHOMA

TULSA, OKLA.—OKLAHOMA NATURAL GAS CO.

DOMESTIC AND INDUSTRIAL

35c per thousand for first 100,000
30c " " " next 400,000
25c " " for all over 500,000

All less 10 per cent. discount if paid within stated period.

OKMULGEE

Domestic	35c per 1,000 cu. ft.
Industrial	10c " " " "

TEXAS

FORT WORTH GAS COMPANY

December 15, 1918

First	20,000 cu. ft.	Net Rate—45c	per thousand
Next	20,000 " "	" " —40c	" "
Next	60,000 " "	" " —35c	" "
Next	150,000 " "	" " —30c	" "
Next	250,000 " "	" " —28c	" "
Next	500,000 " "	" " —26c	" "
Next	1,000,000 " "	" " —25c	" "
Next	3,000,000 " "	" " —24c	" "
Next	5,000,000 " "	" " —23c	" "
Next	10,000,000 " "	" " —22c	" "
All over	20,000,000 " "	" " —21c	" "

GAS RATES IN EFFECT IN TOWNS SUPPLIED BY NORTH TEXAS GAS COMPANY

Domestic at		Cu. Ft.	Gross	Net
Byers, Petrolia, Wichita Falls, Bellevue, Bowie, Sunset, Alvord, Decatur, Bridgeport, Denison, Denton, Witesboro, McKinney	First	20,000	50c	45c
	Next	20,000	45c	40c
	Next	60,000	40c	35c
	Next	150,000	35c	30c
	Next	250,000	30c	28c
	Next	500,000	28c	26c
	Next	1,000,000	27c	25c
	Next	3,000,000	25c	24c
	Next	5,000,000	24c	23c
	Next	10,000,000	23c	22c
	All over	20,000,000	22c	21c
Domestic at Sherman	First	10,000	50c	45c
	Next	5,000	45c	40c
	All over	15,000	40c	35c
Domestic at Electra			40c	36c
Domestic at Corsicana			85c	75c
Industrial at Byers, Petrolia, Wichita Falls			16c	15c
Industrial at Bellevue, Bowie, Sunset, Alvord, Decatur, Bridgeport, Denison, Sherman, Denton, Whitesboro, McKinney			18c	17c
Industrial at Corsicana			85c	75c
Industrial at Electra			40c	36c

$1.00 Minimum at all towns. 25c Readiness to Serve Charge at McKinney.

THE DALLAS GAS COMPANY

Schedule of Rates for Natural Gas

SCHEDULE FOR DOMESTIC SERVICE:

For the first 10,000 cu. ft. of monthly consumption registered on one meter........................50 cents per 1,000 cu. ft.

For the next 5,000 cu. ft. of monthly consumption registered on one meter......................44.5 cents per 1,000 cu. ft.

For all in excess of 15,000 cu. ft. of monthly consumption registered on one meter................38.9 cents per 1,000 cu. ft.

DISCOUNT—PROMPT PAYMENT: A deduction of ten per cent. will be allowed for payment of bill within ten days from the date of monthly billing.

MINIMUM CHARGE: A minimum charge of fifty cents (50c) per meter per month will be made even though customer shall not have used sufficient gas in such month to make the amount of the bill equal such fifty cents.

SCHEDULE FOR BOILER SERVICE:

For the first 250,000 cu. ft. of monthly consumption registered on one meter.....................27.78 cents per 1,000 cu. ft.

For all over 250,000 cu. ft. of monthly consumption registered on one meter.....................18.89 cents per 1,000 cu. ft.

DISCOUNT—PROMPT PAYMENT—BOILER SERVICE: A deduction of ten per cent. will be allowed for payment of bill within ten days from the date of monthly billing.

MINIMUM CHARGE: A minimum charge of Fifty ($50.00) Dollars per meter per month will be made even though customer shall not have used sufficient gas in such month to make the amount of the bill equal such Fifty Dollars.

APPLICATION OF BOILER SCHEDULE: This schedule applies to gas in quantities of 200,000 cubic feet or more per month under steam and hot water boilers (except in residences), in brick kins, furnaces, brick bake furnaces, cement kilns, glass furnaces, and in iron and steel mills. Company to have the right to restrict customer's demand at any time, and for such periods as may in the judgment of Company be necessary to enable Company to supply its domestic customers.

WEST VIRGINIA

Supplement No. 5 to
Natural Gas Rate Schedule, P. S. C. W. Va. No. 5

HOPE NATURAL GAS COMPANY

RATES—CLASS 1. DOMESTIC CONSUMERS

Belmont, Eureka, Lima, Clarington, and neighboring country districts and villages: (a)

28 cents per thousand cubic feet, less two cents per thousand cubic feet for payment within the discount period. (A) Parkersburg*, Williamstown, Sistersville, Friendly, Paden City, St. Marys, and neighboring country districts and villages: (b)

25 cents per thousand cubic feet, less two cents per thousand cubic feet for payment within the discount period. (A) Minnora, Lost Creek, Smithfield, Littleton, Wileyville, Metz, Glovers Cap, Fairview, and neighboring country districts and villages: (a)

26 cents per thousand cubic feet, less two cents per thousand cubic feet for payment within the discount period. (A) Mannington, Mt. Clare, Pine Grove, and neighboring country districts and villages: (b)

23 cents per thousand cubic feet, less two cents per thousand cubic feet for payment within the discount period. (A) Colliers: (a)

32 cents per thousand cubic feet, less two cents per thousand cubic feet for payment within the discount period. (A)

(*)—As to the City of Parkersburg, the increase in domestic rates shall become effective from and after the first day of August, 1920, unless hereafter otherwise ordered by the Commission.

RATES—CLASS II. GAS ENGINES

Belmont, Eureka, Lima, Clarington, and neighboring country districts and villages: (a)

28 cents per thousand cubic feet for the first 500,000 cubic feet used in each calendar month, and for all over 500,000 cubic feet used in a calendar month, 23 cents per thousand cubic feet.† (A)

Parkersburg, Williamstown, Sistersville, Friendly, Paden City, St. Marys, and neighboring country districts and villages: (b)

25 cents per thousand cubic feet for the first 500,000 cubic feet used in each calendar month, and for all over 500,000 cubic feet used in a calendar month, 20 cents per thousand cubic feet.† (A)

Minnora, Lost Creek, Smithfield, Littleton, Wileville, Metz, Glovers Gap, Fairview, and neighboring country districts and villages: (a)

26 cents per thousand cubic feet for the first 500,000 cubic feet used in each calendar month, and for all over 500,000 cubic feet used in a calendar month, 21 cents per thousand cubic feet.† (A)

Mannington, Mt. Clare, Pine Grove, and neighboring country districts and villages: (b)

23 cents per thousand cubic feet for the first 500,000 cubic feet used in each calendar month, and for all over 500,000 cubic feet used in a calendar month, 18 cents per thousand cubic feet.† (A)

Colliers: (a)

32 cents per thousand cubic feet for the first 500,000 cubic feet used in each calendar month, and for all over 500,000 cubic feet used in a calendar month, 27 cents per thousand cubic feet.† (A)

(†)—Discount: Less two cents per thousand cubic feet for payment within the discount period.

RATES—CLASS III.

Belmont, Eureka, Lima, Clarington, and neighboring country districts and villages; also Wood and Pleasants Counties; and Calhoun, Ritchie, Wirt, southwest portion of Tyler and western portion of Gilmoer Counties, known as Schultz and Southern Districts on the books of the Company (including gas by meter for field operations in said districts, such as drilling wells, cleaning out, pumping oil and water, etc.): (a)

27 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 21 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 18 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.‡ (A):

Parkersburg, Williamstown, Sistersville, St. Marys, Friendly, Paden City, and neighboring country districts and villages: (b)

24 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 18 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 16 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.† (A)

Mont Clare, Minnora, Lost Creek, Smithfield, Littleton, Wileville, Metz, Glovers Gap, Fairview, and neighboring districts and country villages, and places included within the sub-divisions known on the books of the Company as the following working districts: Bridgeport, Buffalo, Fairview, Fink, Kanawha, Pine Grove, Mannington, Littleton, Salem, Shirley, Weston, and Wetzel (including also gas by meter for field operations such as drilling wells, cleaning out, pumping oil and water, etc., in said districts): (a)

25 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 21 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 17 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.† (A)

Mannington and Pine Grove, and neighboring country districts and villages: (b)

22 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 17 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 15 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.† (A):

Ideal Window Glass Company, near West Union: (a)

25 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 21 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 15 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.† (A):

(†)—Discount: Less one cent per thousand cubic feet for payment on or before the 20th day of the month following that in which the gas is supplied.

RATES—CLASS IV.

Entire territory, excepting places noted under exceptions: (a)

20 cents per thousand cubic feet, net. (A)

NOTE—Exceptions:

Fairview Borough Buildings: (a)

10 cents per thousand cubic feet, net, until expiration of ten year contract June 23, 1919; thereafter at the published rate above set forth for the entire territory.

Wood County Public Jail and Court House: (b)

19 cents per thousand cubic feet, net. Right of way contract rate. (A)

RATES—CLASS V.

Parkersburg City Hall and City Utilities, and Sistersville City Water Works: (b)

24 cents per thousand cubic feet for the first 150,000 cubic feet consumed in a calendar month; 18 cents per thousand cubic feet for the second 150,000 cubic feet consumed in a calendar month; 16 cents per thousand cubic feet for all over 300,000 cubic feet consumed in a calendar month.† (A)

Mannington Water Works: (b)

Six cents per thousand cubic feet, net.

(†)—Discount: Less one cent per thousand cubic feet for payment on or before the 20th day of the month following that in which the gas is supplied.

NOTE TO ALL METER SERVICE: (b)

Meter service is based upon a meter pressure not exceeding eight ounces. If gas is supplied at a higher pressure, the meter measurements are corrected according to Boyle's Law.

FLAT RATE SERVICE: (a)

Field Operations Such as Drilling Wells, Cleaning Out, Pumping Oil and Water, Etc., Applicable only in the Case of Isolated Wells, All Others Being Embraced in the Meter Rate for Class III.

Entire territory:	
Drilling or cleaning out wells, boiler, single tour of 12 hours or less, $4.00; double tour	$ 7.50 (A)
Forge for drilling or cleaning out, per tour of 12 hours or less	.50 (A)
Lawn lights for drilling well, per night	.50 (A)
Heating stove with mixer, November 1st to April 1st, per month	7.50 (A)
Pumping water for drilling or cleaning out, per day for total days of drilling or cleaning out	1.00 (A)
Pumping wells with boiler and engine, per month, steam**	15.50 (A)
Pumping wells with gas engine, first well, per month	7.50 (A)
Each additional well on same gas engine	3.00 (A)
Cleaning out wells, per tour 12 hours or less, gas engine	1.50 (A)
Steaming oil, pumping out oil, per tank of 600 barrels, each service	4.00 (A)
Steaming oil, pumping out oil, per tank of 250 barrels, each service	1.75 (A)
Steaming oil, pumping out oil, per tank of 100 barrels, or under, each service	1.00 (A)
Pumping water, Donkey pumps, jetting water, steam, per tour 12 hours or less	2.00 (A)

**Charge for pumping wells is $15.50 per month each, whether gas is used one day or a full month.

Pulling casing, rods,* or tubing wells, * 12 hours or less, steam	3.50 (A)
Pulling casing, rods, or tubing wells,* 12 hours or less, gas engine	2.00 (A)
Drilling machines, 10 H. P. or less, per tour 12 hours or less	3.00 (A)

*No charge for tubing or pulling rods on pumping wells when rate of $15.50 per month for pumping same is paid.

NOTE—The above rates are for low pressure burners only; high pressure burners using two pounds or more gauge pressure to the square inch are not permitted; in other respects the rates apply to the customary gas burning appliances in general use; if special appliances are used rates will be quoted on application. (N)

NOTE—The Lawn Lights hereinbefore mentioned are Irwin's lawn lights or burners of like capacity.

STREET LIGHTING: (a)

The rates for street lighting service, based upon the use of natural gas from 5 P. M. to 7 A. M. of each day from April 1st to October 1st, and from 4 P. M. to 8 A. M. each day from October 1st to April 1st, the consumer furnishing and maintaining the lamps, are as follows:

Entire territory, excepting in places noted under exceptions:

$5.00 per year for each lamp with one mantle, and $2.50 per year in addition for each additional mantle in each lamp. (A)

NOTE—Exception.

Fairview: Ten cents per mantle per month, until June 23, 1919; thereafter at the published rate above set forth for the entire territory.

SPECIAL FLAT RATES: (b)

Mannington: One garbage fire, $10.00 per month.

Dated January 27, 1919.

(a)—Effective, March 1, 1918, by order of The Public Service Commission of West Virginia, entered March 20, 1918. in Case No. 663.

(b)—Effective, as to domestic consumers, from and after the last meter reading in month of December, 1918, excepting as to the City of Parkersburg, and as to said City the increase in domestic rates shall become effective from and after the first day of August, 1920, unless hereafter otherwise ordered by the Commission; as to all other classes of consumers, effective date January 1, 1919. By order of The Public Service Commission entered January 11, 1919, Case No. 663.

PART FIFTEEN

INDUSTRIAL CONSUMPTION OF GAS

COMPARATIVE FUEL VALUE — FACTS AND FIGURES ABOUT NATURAL GAS USED IN VARIOUS INDUSTRIES — BOILER INSTALLATION (SECTION)—GAS ENGINE (SECTION)—POWER (SECTION).

Comparative Fuel Value of Coal, Oil and Natural Gas— Good practice, with boilers of proper construction and proportioned to the work:

1 lb. of coal will evaporate 9 lb. of water from and at 212 deg. fahr

1 lb. of oil will evaporate 13 lb. of water from and at 212 deg. fahr.

1 lb. of natural gas will evaporate 15 lb. of water from and at 212 deg. fahr.

1 lb. of coal will equal 12 cu. ft. of natural gas.

1 ton of coal (2000 lb.) will equal 24,000 cu. ft. of natural gas.

1 lb. of oil will equal 17 cu. ft. of natural gas.

1 bbl. (42 gal.) will equal 5,000 cu. ft. of natural gas.

5 bbl. (42 gal.) will equal 1 ton of good coal.

1 cu. ft. of natural gas will evaporate 0.75 lb. of water.

1 cu. ft. of natural gas contains 990 B. t. u. gross.

1000 cu. ft. of natural gas contains 990,000 B. t. u.

1 ton of coal contains 24,000,000 B. t. u. to 28,000,000 B. t. u.

1 bbl. of oil contains 5,600,000 B. t. u.

1 bbl. of oil 41 deg. gravity, weight 287.5, U.S. bbl., contains 5.615 cu. ft.

1 cu. ft. of water at 39.8 deg. fahr. at 30 inches of mercury, atmospheric pressure, weighs 62.42 lb.

Under fair conditions a 100 h. p. boiler will use about 4000 lb. of R. M. bituminous coal in ten hours.

In the foregoing values only good quality coal, gas and oil are considered. Natural gas varies greatly in B. t. u. tests from 748 B. t. u. to 1100 B. t. u. 990 is a good average quality.

. The quality of coal with reference to B. t. u. varies greatly in different mines and commonly in the same mine.

It should be borne in mind that in the use of coal there is always a waste of fuel in starting the fire under a boiler and after the work is finished. With gas or oil for fuel, less time is required in starting the fire, and after the work is completed the fire can be put out immediately.

Facts and Figures about Natural Gas as Used in Various Industries.

ELECTRICITY—The amount of gas required in making electricity with steam installation, using gas for fuel, is 40 cu. ft. per kilowatt hour. With a gas engine the amount of gas required for making electricity is about 18 cu. ft. per kilowatt hour

CEMENT—The amount of gas required to make one barrel of cement, in plants of more than 1000 barrels daily capacity, is 3000 cu. ft. For the burning only of one barrel of cement in kilns, 1750 cu. ft. of gas is required.

SMELTER—The amount of gas required in a smelter to burn one block of 640 retorts for twenty-four hours is between 600,000 and 700,000 cu. ft. of gas, dependent on the kind of ore smelted. In plants of three blocks or more, it is generally figured that 1 000,000 cu. ft. of gas is required for each block, which figures include roasting, pottery, and boiler use.

BRICK—The amount of gas required in making one thousand brick is as follows:

For burning	12,000 cu. ft.
For drying	1,700 cu. ft.
For steam	1,900 cu. ft.
Total	15,600 cu. ft.

MULTIPLE GAS BURNER TEST

Under No. 9 Boiler at S. J. L. & P. Corporation Steam Plant, Bakersfield, Calif., Jan. 29, 1919.

600 H. P. boiler with superheat

Orifice disc used, 6x3; gravity, 69; temperature, 60. deg.; barometer, 14.60 lb.

Coefficient used, 2660

Steam pressure ranged from 198 to 202 lb.—used 200 lb.

Superheat ranged from 472 to 499 deg.—averaged 483 deg.

Stack temperature averaged from 470 to 580 deg.—averaged 485 deg.

Feed water did not vary from 64 deg. fahr.

Test ran from 9:05 A. M. to 4:05 P. M.—7 hrs.

Water, steam, etc., at same level start and finish. Draft .21

Weighed water at 64 deg. fahr. equals 115,111 lb.

Correcting factor used for from and at 212 deg. equals 1.460

Corrected amount of water used equals 168,100 lb.

Amount of gas used by formula $Q = C\ (\sqrt{H\ (P+14.60)})$ equals 183,822 cu. ft.

Lb. of water evaporated to cu. ft. of gas, .915

Allowing oil to evaporate 14 lb. of water to 1 lb. of oil and deduct 3 per cent for steam to burners and 336 lb. of oil to a 42 gal. bbl.

Boiler horsepower developed per hour equals 569

4704 lb. of water evaporated by bbl. of oil equals 4704 lb. less 3 per cent equals 4563 lb. of water, equals 4563 div. by 0.915 equals 5000 cu. ft. of gas equals 1 bbl. of oil

Gas burned under pressure of 1.5 inches of mercury or ¾ lb.

BOILER BURNER INSTALLATION (Section)

Boiler Burners for Natural Gas—The secret of success in the use of gas burners under boilers is to thoroughly mix the proper amount of air and gas before these factors reach the point of ignition.

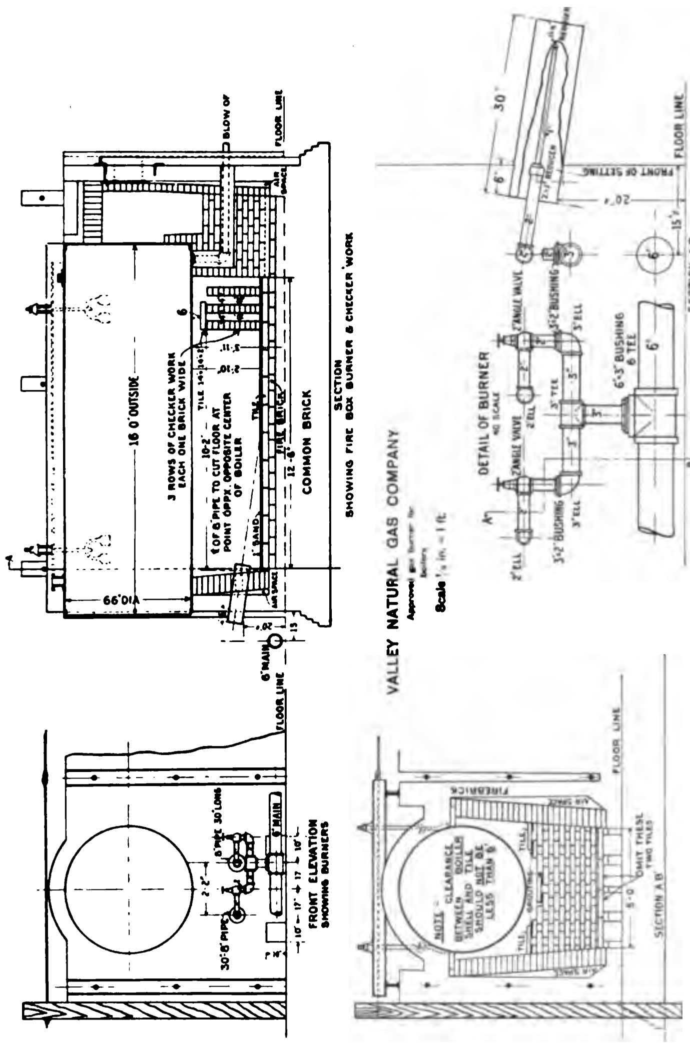

FRONT ELEVATION
SHOWING BURNERS
SECTION
SHOWING FIRE BOX BURNER & CHECKER WORK
16' 0" OUTSIDE
66" DIA
3 ROWS OF CHECKER WORK
EACH ONE BRICK WIDE
COMMON BRICK
FIRE BRICK
6" MAIN
FLOOR LINE
VALLEY NATURAL GAS COMPANY
DETAIL OF BURNER
NO SCALE
SECTION AB
FRONT OF SETTING
FIREBRICKS
OMIT THESE TWO TILES

Fig. 201

Complete combustion requires the union, under high temperature, of one atom of carbon to two atoms of oxygen. The combustion of one pound of carbon, when supplied and thoroughly mixed with the above amount of oxygen, will produce 14,500 B. t. u.; while one pound of carbon, when supplied with half the above amount of oxygen, will produce only about 4500 B. t. u. In the first case the resulting product of combustion is carbon dioxide, CO_2 and, in the second, carbon monoxide, CO.

It is very important that the gas and oxygen be thoroughly mixed after they have been brought together, as the completeness of combustion obtained will depend upon the manner in which they have been mixed. A perfect mixture can be obtained only by putting gas and oxygen in violent agitation before reaching the combustion chamber, for even though the proper proportion of oxygen be present, it may not have a chance to reach all of the carbon atoms to unite with them before the gases pass out of the combustion chamber and become chilled below the temperature of ignition. For this reason it is also necessary to supply more air than is theoretically required for complete combustion.

Temperature of Natural Gas Combustion—Natural Gas combustion, when supplied with the exact amount of air necessary for complete combustion, should burn at a temperature of about 4200 deg. fahr. On account of the excess of air that is necessary for dilution, however, the actual temperature of combustion is about 2200 deg. fahr. It is not always desirable to use an extremely high temperature as in some cases it would injure the products of the furnace in which it is being used. This would apply to the burning of brick or any other material which is placed in a kiln, and fired after the setting is completed. For this purpose the temperature should be very low when started, and gradually increased as the kiln is heated. When combustion of gas takes place, much moisture is liberated in the form of vapor,

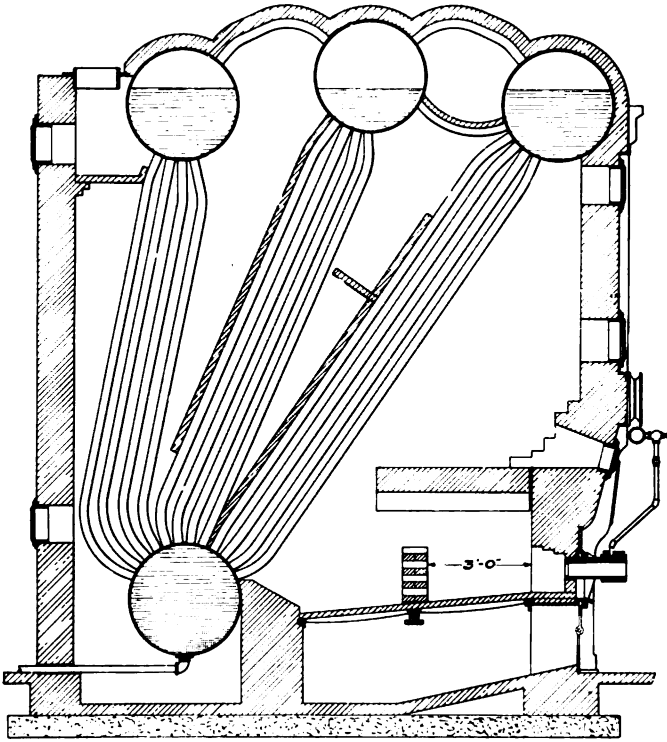


Fig. 202—NATURAL GAS INSTALLATION UNDER WATER TUBE BOILERS

which will be condensed on the surface of any object which is at a low temperature and will be absorbed by any object which will retain moisture. This is objectionable for some purposes.

Installation of Natural Gas Burners Under Boilers—While there can be a great many different methods employed in installing natural gas burners under boilers, they all vary but slightly from each other. In covering this subject, we are making some general suggestions as adopted by gas burner experts.

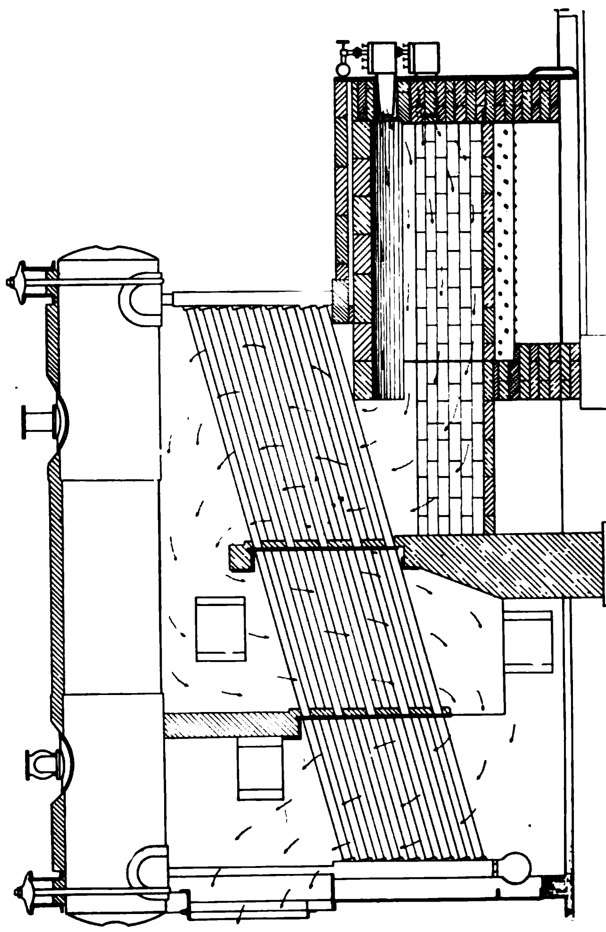


Fig 203—NATURAL GAS INSTALLATION UNDER MURPHY OR SIMILAR TYPE OF BOILERS

Cover the entire grate surface (or bottom of furnace if grates are not used) with fire brick or any material that will stand a high temperature, for the purpose of excluding all air and to protect the grates from the heat of the furnace.

Primarily it must be borne in mind that the greatest success with natural gas under boilers is to burn all the combustible with the proper mixture of air.

Place the burners under the fire doors or through holes cut in the front of the furnace as shown in cuts. If burners are placed through the doors, the opening around the burners should be built up with brick and mortar. The burners should not extend beyond this brick wall.

The distance from the end of the burners to the checker-wall will vary under different conditions. Checker-walls should be nine inches thick, and where a three-foot or higher wall is required the thickness should be increased at the bottom and tapered off towards the top. If the wall is not increased in thickness at the bottom, it will not be apt to stand long where it is three feet high or over. A space of one or two inches should always be left at each end of the wall where it joins the side wall to the furnace.

These two spaces are for the purpose of allowing expansion and contraction, which would be liable to throw the wall down unless provided for as above specified.

The height of the wall will depend upon the construction of the furnace, the purpose for which it is being used, and the amount of gas to be consumed. If it is to be used in a boiler furnace and it is desired to work the boiler at or above its rating, care should be taken that the wall is not built up too close to the boiler, as the heat generated will be intense if confined too much in front of the furnace by reason of the checker-wall being built too high or the openings too small.

The object of the checker-wall is to retard slightly the velocity of the burning gas in order to obtain greater benefit where needed, rather than to have the burning gas pass

quickly into the hood and stack, spreading the effects of the heat en route.

Should the work the boiler is required to do be light, and at no time exceed the rating of the boiler, the checker-wall can be built with smaller openings and closer to the boiler with better results. In case the draft is very poor and not sufficient for the amount of work being done, a second checker-wall, placed about one foot back of the first, will give better results. If the second wall is used, some air should be admitted from the bottom of the furnace between the two checker-walls.

In a furnace covered by an arch and entirely surrounded with fire-brick, a small amount of checker-wall will be sufficient. In many cases none is required, as the heat generated will be all the furnace will stand without any checker-wall.

As all furnaces are not alike, it is impossible to give instructions that will cover every case. Therefore, any wall or combination of walls that will give the best results is the proper thing to use in that particular case.

In a boiler with a horizontal baffle, where the gases pass to the rear of the furnace, the checker-wall should be about thirty inches from the front wall of the furnace. In selecting the proper size header for a boiler setting, we would suggest the following formula by Gwynn:

$$A = \sqrt{B \times C}$$

A = Diameter of pipe in inches.

B = Area of gas connection to burner.

C = Number of burners used.

Example—It is proposed to install ten five-inch gas burners with one-and-one-half-inch gas sconnections; what size header would be required? A one-and-one-half-inch gas pipe equals 2.036 in area. As ten burners are to be fed from this header, the area required would be the area of gas connection to burner, multiplied by the number of burners to be used. In applying these figures to the above formula,

the result would be about a five-inch pipe, which would be the smallest size pipe used in this case.

A valve should be placed in the header at the side of the boiler for the purpose of regulating the volume of gas supplied to all burners at one time.

Continue away from header with a gas line of the same size. If this line extends more than twenty or thirty feet a larger size should be used, as the gas pressure will decrease very rapidly in a long line, especially if there are many turns.

Use of Steam or Compressed Air in Boiler Burner Installations—In very few cases the use of steam in connection with boiler burners is a benefit. In all of such cases some of the following conditions will be present: insufficient draft to carry away the products of combustion; insufficient burner capacity; insufficient boiler or furnace capacity to do the work required; insufficient gas pressure at the burner; installations not properly made; burners not opera ed in the proper manner. Any or all of these conditions might be present at the same time. When steam is used it is only for the purpose of forcing the proper mixture between the gas and air when this cannot be done in any other manner. This is accomplished by the steam entering the mixing chamber under the same pressure through several very small jets with a spiral or rotary motion and causing a partial vacuum in the air tube, which, in turn, causes the air to flow into the burner and become thoroughly mixed with the gas before reaching the point of ignition. Compressed air may be used for this purpose with much better results, as the only loss will be the power required to compress the air.

The use of steam in a gas-fired furnace is always attended with a loss, as the heat absorbed by the reduction of one pound of steam to hydrogen and oxygen is much greater in amount than the heat generated by the union with the carbon of oxygen thus set free. This loss may be partially

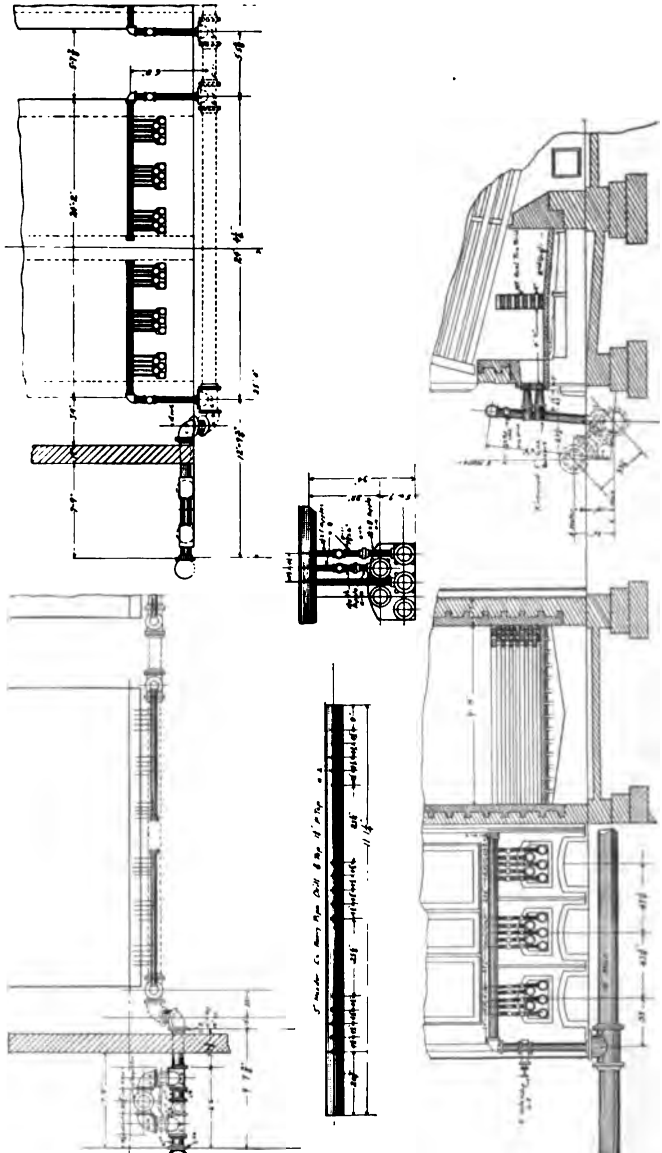


Fig. 204 -PLAN OF NATURAL GAS BURNER INSTALLATION UNDER BOILER
(See detailed list of specifications on page 577)

FITTINGS ON GAS MAIN

Symbol
C-1 Five 12-inch Cast Iron Flanged Tees, faced and drilled.
C-2 Two 10-inch Cast Iron Flanged Tees, faced and drilled.
C-3 Three 12-inch Cast Iron Flanged Ells, faced and drilled.
C-4 Two 10-inch Cast Iron Flanged Ells, faced and drilled.
C-5 Three 10-inch Cast Iron Flanged Gate Valves.
C-6 Twelve 12-inch Cast Iron Flanges faced and drilled.
C-7 Six 5-inch Cast Iron Flanges, faced and drilled (5-inch pipe tap, outside diameter 19 inches).
C-8 One 10-inch Cast Iron Flange, faced and drilled (10-inch pipe tap, outside diameter 19 inches).
C-9 Five 10-inch Cast Iron Flanges, faced and drilled (10-inch pipe tap, outside diameter 16 inches).
C-10 Three 12-inch Wrought Iron Pipes (threaded), about 22 feet 4 inches long.
C-11 Two 12-inch Wrought Iron pipes (threaded), about 3 feet 5 inches long.
C-12 One 12-inch Wrought Iron Nipple (threaded), about 10 inches long.
C-13 One 10-inch Wrought Iron Nipple (threaded).
C-14 One 10-inch Wrought Iron Nipple.
C-15 One 10-inch Wrought Iron Pipe, about 3 feet 3¾ inches long.

BILL OF MATERIAL FOR ONE BOILER

Symbol
A-1 Fifteen 5-inch Gas Burners.
A-2 One 5-inch Wrought Iron Header.
A-3 One 5-inch Cast Iron Cap.
A-4 One 5-inch Cast Iron Ell.
A-5 One 5-inch Cast Iron Gate Valve.
A-6 One 5-inch Wrought Iron Long Nipple, 12 inches long.
A-7 One 5-inch Wrought Iron Pipe (threaded), about 3 feet 10 inches long.
A-8 Fifteen 1¼-inch Wrought Iron Long Nipples, 6 inches long.
A-9 Nine 1¼-inch Wrought Iron Long Nipples, 8 inches long.
A-10 Twelve 1¼-inch Wrought Iron Long Nipples, 3½ inches long.
A-11 Fifteen 1¼-inch Cast Iron Stop-Cocks.
A-12 Fifteen 1¼-inch Malleable Iron Dart Unions.
A-13 Nine 1¼-inch Nipples, 6 inches long.
B-1 Two hundred and forty-two 9-inch Fire Bricks, to cover grates. (Use second quality).
B-2 Two hundred and thirty-two 9-inch Fire Bricks, for checker wall. (Use Benezet).
B-3 Ten 9x4½x1¼-inch Fire Brick Splits, for filling doors.
B-4 One Sack Fire Clay.

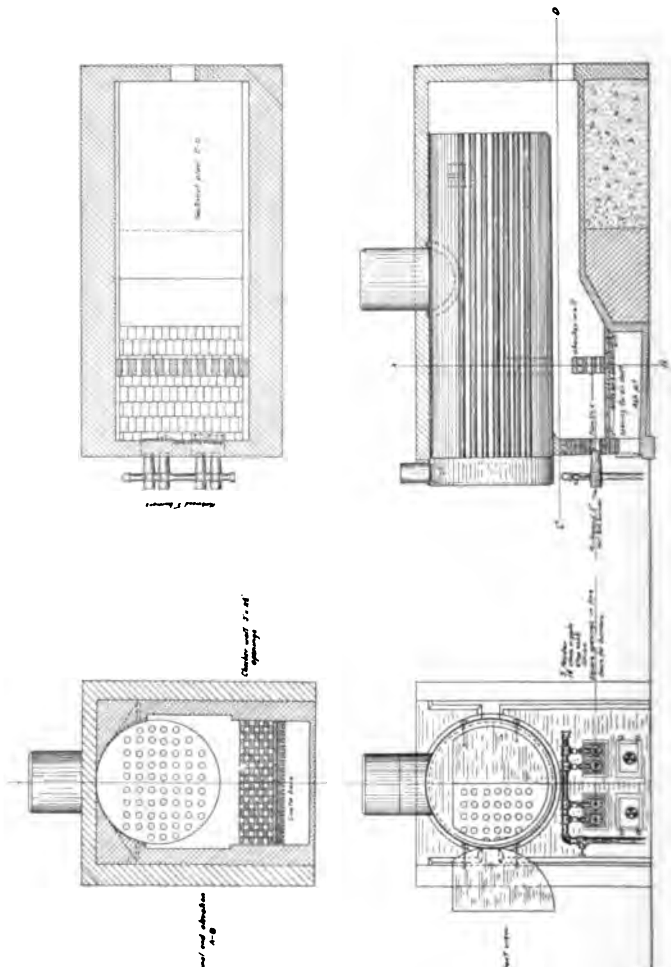


Fig. 205

recovered if the furnace is kept at the proper temperature to quickly reduce the steam to hydrogen, which will be consumed with the gas.

Draft—In lighting a furnace which has been closed down, care should be used to see that the damper is open and that there is enough draft to carry away the products of combustion; otherwise, the flame will soon be extinguished and the escaping gas may cause trouble if re-ignited. Any serious obstruction to the draft while boiler or furnace is in operation might have the same effect.

A very simple method of increasing the economy of the burning of gas under a boiler, whether an analysis of stack gas is made or not, is to use a screw damper in connection with a common siphon gauge to measure the stack draft. As a rule the screw damper is a home-made affair designed to regulate the draft and carry continually a suction or minus pressure in the stack as shown on the gauge. A common four-inch siphon gauge should be located in close proximity to the damper regulator or screw and the damper regulated according to the pressure. The screw attachment on the damper permits of delicate and careful regulation of the damper opening.

The best suction pressure or draft to carry must be determined by actual tests. After once determined it should be checked by subsequent tests two or three times a year. To make this test the screw damper and gauge must be installed first and a certain stack pressure carried on the gauge continuously during the entire length of each individual test.

It is a well-known fact that changes in atmospheric conditions such as barometer, temperature and humidity, greatly affect the draft in any chimney or stack. With the screw damper and siphon gauge, an even stack pressure best suited to the boiler conditions can be carried at all times.

A special draft gauge will indicate the suction or minus pressure more closely than the common siphon gauge but is a more expensive instrument.

Generally the draft of medium sized stacks or chimneys will be about one or two-tenths inches water pressure.

Draft Gauge—The draft gauge is a modification of the ordinary U tube gauge, one of the tubes being expanded in a

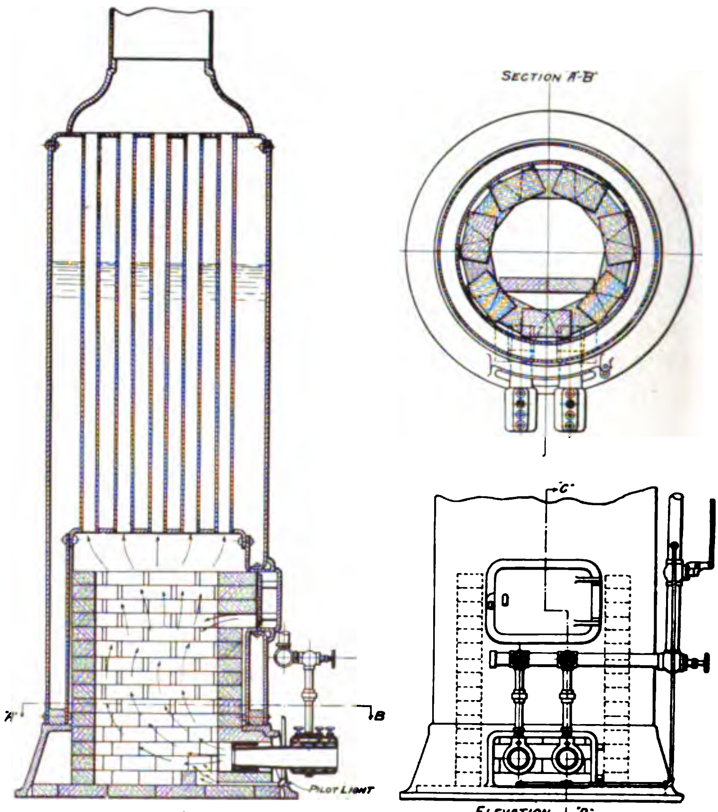


Fig. 206—NATURAL GAS BURNERS AS APPLIED TO VERTICAL TUBULAR BOILERS

reservoir and the other inclined at an angle to the latter, angle of inclination being in accordance with the desired length of the scale. This lengthens each one inch of vertical scale into a scale five or ten inches long as desired, and thus 1-100 of an inch pressure on the differential gauge is as easily determined and read as 1/10 of an inch on the ordinary gauge.

The fluid employed for filling is the oil known as "Mineral Seal," having a specific gravity 39 to 40 Beaume, and is preferable to water because its capillary attraction is much less, thus producing more accurate indications. The evaporation is also much less than water.

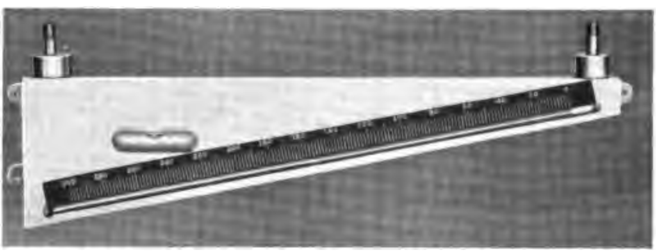


Fig. 207—DRAFT GAUGE

Operation of Natural Gas Burners for Boiler Use—In addition to careful installation, the success of a gas burner depends somewhat on the manner in which it is operated. After the installation has been completed and the burners are ready to put in operation, see that all the valves of the gas line leading to the burners are closed, also that the damper in the stack is open enough to carry away the products of combustion. A torch can be lighted and placed through the center of a burner or through an opening beside it before gas is turned on to this individual burner. When one burner has been lighted the others can be turned on, one at a time,

each igniting from the preceding one; or if too far apart each will have to be lighted as was the first one.

Under no consideration should a gas valve be opened until the light has been put into the furnace, as enough gas will accumulate in the furnace in a few seconds to do some damage if lighted suddenly. After burners have all been put in operation, see that there is sufficient draft to carry away the products of combustion. Where there have been just two or three burners used and the checker-walls have become "white heat" and the burners have either accidentally been turned off or gone out, the lighted torch should be placed in the furnace to ignite the gas before a burner is turned on again. It should not be expected that gas will ignite from the white-heated checker-wall. Actual ignition is apt to be delayed until considerable gas has accumulated in the furnace, thereby causing a dangerous explosion. Under no circumstances, in case the gas flame goes out, should one depend upon the white-heated checker-wall to ignite the gas.

When the furnace is cold it should be heated up slowly, as it might damage the brick work if heated too rapidly. Only enough burners should be used to do the work required, as their economy will be better when they are worked at their full rating.

Gas should not be used at a greater pressure than ten or twelve ounces. Results will not be so satisfactory as if used at a lower pressure. Satisfactory results have been obtained on small installations with burners as low as one-half ounce pressure.

A good draft is absolutely essential, especially if the furnace is working at a high rating, and should always be maintained.

A gas-fired furnace should burn with a clear blue flame and white heat and with as little white flame as possible. The presence of white flame indicates carbon monoxide, (CO), which means bad combustion.

As no two boilers or furnaces will work exactly alike, no positive instructions can be given which will cover all cases. The object, however, is to secure as nearly perfect combustion as possible. Therefore, any valve or combination of valves or other conditions which will obtain that result are the proper ones to use, regardless of any other instructions.

SOME CAUSES RESPONSIBLE FOR FAILURES WITH NATURAL GAS BURNERS

Leak of gas supply at burner.
Pipes too small and too many turns.
Pipes clogged by corrosion or other foreign matter.
Burner openings clogged with dirt.
Burner capacity too small for work it does.
Draft not sufficient for work being done.
Burners not properly installed.
Burners not properly operated.

It is not probable that all these defects will be present in any one case, but some of the above defects will be found to exist where failures result.

Boiler Testing—There have been many cases where boiler tests have shown a great loss of fuel through improper mixture of gas and air in the burner. Although the cost of the boiler test is rather expensive, and though it may not show any possibilities of saving fuel, it is a great satisfaction to the interested party to learn whether they are obtaining the full benefit from the gas.

In making a boiler test where natural gas is used as fuel in a patent burner, the following suggestions should be followed: Prior to making test the boiler should be thoroughly examined and should be absolutely free from any scale. The area of the heating surface should be figured next, using the diameter of the tube next to the water. The surface below the mean level of the water is termed as a rule, "water

heating surface," and the surface above the mean level of the water is called "superheating surface."

Install new or lately tested gas and water meters, using a low-pressure regulator back of gas meter to enable the carrying of an even pressure of gas. In laying out the gas line it should be provided with a mercury gauge and a thermometer well to obtain the pressure and the temperature of the gas. Inasmuch as the temperature of the feed water should be kept as high as possible in order to get the maximum efficiency from the gas, it is necessary to use a hot water meter. If a feed pump is used, the meter should work on the boiler side of the pump and the working pressure of the pump be kept as constant as possible. If an injector is used on the water line feeding the boiler, it should receive the steam directly from the boiler while being tested, and the feed water should be passed through the hot water meter after being thrown out by the injector.

Prior to starting test, the boiler should be heated up for at least three or four hours and put into service on the main steam line. A test should last from ten to twenty-four hours and a log sheet kept of all meter readings, temperatures, drafts and steam pressures. All notations should be made hourly or oftener. The reading of gas and water meters should be taken at the beginning and every twenty minutes thereafter to the end of the test.

At the time of starting a test the level of the water should be marked on the gauge glass by scratching with a file or tying a piece of wire or string around the glass.

Temperatures should be taken of the steam, feed water, stack, and gas and air in the engine room and outside of the building.

The draft should be measured with water in a U tube both in the furnace and the hood of the stack. The steam pressure and gas pressure should be noted hourly. Any

heavy or sudden pull on the boiler should be mentioned under the head of "Remarks."

The test should be absolutely uniform with respect to load to get the conditions of maximum economy, but to show the sensitiveness of the burner and boiler, a variable load should be used.

A calorimeter test is important to ascertain the quality of the steam, *i. e.*, whether the steam is "saturated" or contains the quantity of heat due to the pressure according to standard experiments; second, whether the quantity of heat is deficient, causing the steam to be wet; and third, whether the heat is in excess and steam superheated.

The method commonly employed is the barrel calorimeter, which with careful operation and fairly accurate instruments may generally be relied upon to give results within two per cent.

The calorimeter is described as follows: A sample of steam is taken by inserting a perforated one-half-inch pipe into and through the main pipe near the boiler and conducted by a hose, thoroughly felted, to a barrel holding preferably 400 pounds of water, which is set upon a platform scale provided with a valve for allowing the water to flow to waste and with a small propeller for stirring the water.

The barrel is filled with water, the weight and temperature ascertained, steam blown through the hose outside the barrel until the pipe is thoroughly warm, when the hose is suddenly thrust into the water and the propeller operated until the temperature of the water is increased to a desired point, usually about 110 deg. The hose is then withdrawn quickly, the temperature noted, and the weight again taken.

An error of one-tenth pound in weighing the condensed steam or an error of one-half degree in temperature will cause an error of over one per cent. in the calculated percentage of moisture.

The calculation of the percentage of moisture is made as follows (Kent's "Mechanical Engineer's Book"):

$$Q = \frac{1}{H - T}\left[\frac{W}{w}(h_1 - h) - (T - h_1)\right]$$

Q = Quality of steam, dry saturated steam being unity.

H = Total heat of one pound of steam at the observed pressure.

T = Total heat of one pound of water at the temperature of steam of observed pressure.

h = Total heat of one pound of condensing water, original.

h_1 = Total heat of one pound of condensing water, final.

W = Weight of condensing water corrected for water-equivalent of the apparatus.

w = Weight of the steam condensed.

Percentage of moisture = $1 - Q$.

If Q is greater than unity, the steam is superheated, and the degrees of superheating equal 2.0833 $(H - T)$ $(Q - 1)$.

For accurate determination, all the steam made by the boiler should be passed through a separator, the water separated should be weighed, and a calorimeter test made of the steam just after it has passed the separator. The percentage of water extracted by the separator should then be added to that determined by the calorimeter to give the total percentage of mixture in the steam.

The throttling calorimeter is a convenient and accurate instrument for determining the quality of the steam. For description, see any treatise on boiler or boiler testing.

The analysis of gas to be used, while not always required, is necessary for an exhaustive test, and from this analysis the calorific value of the fuel can be calculated; or, better still, this value may be directly determined by some standard form of calorimeter, such as the Junker's.

A chemical analysis of the stack gas should be carefully made by a chemist to determine the existence of unburnt

gases caused by improper mixture of gas and air in the burner. Samples of stack gas should be taken hourly and the analysis can be made by the common Orsat apparatus to show the carbon dioxide, carbon monoxide, oxygen and nitrogen. From these results the excess of air used by the burner can be calculated. (See Stack Gas Analysis, page 589.)

The method for calculating the boiler efficiency is as follows: Divide the heat absorbed per hundred feet of gas by the calorific value of one hundred cubic feet of gas supplied. From the results obtained from the log sheet, the approximate heat balance or statement of the distribution of heating value of the gas may be obtained.

The gas per hour should be calculated, together with the gas per square foot of heating surface per hour. The total weight of water feed can be calculated from the meter readings, and the feed water temperature by referring to any table which gives the weight per cubic foot of water under different temperatures. The equivalent water fed to the boiler from and at 212 deg. fahr. may be ascertained from a table of factors of evaporation, after having been corrected for moisture in the steam.

The horse power, which is determined at 34½ pounds of water evaporated from and at 212 deg. fahr., may be figured from the last results. The builder's rated horse power is obtained from the boiler specifications and the percentage of boiler's rated horse power calculated.

One boiler horse power is the evaporation of 34½ pounds of water per hour from a feed water temperature of 212 deg. fahr., to steam at the same temperature (spoken of as "from and at 212 deg. fahr.") and is equal to 33,305 B. t. u. per hour.

Testing Gas Burners—The only fair way of testing a gas burner is to analyze the flue gases, a sample of which should be taken as near the point of combustion as possible having all air leaks well stopped in the boiler setting back of the flue

TABLE No. 87—The Properties of Saturated Steam

	Temp. Deg. Fahr.	Heat of the Liquid	Latent Heat	Total Heat	Weight of 1 Cubic Foot, Lb.	Volume of 1 Lb., Cubic Feet
	t	h	L	H	S	Q
Vacuum In. Mer.						
25	133.2	101.1	1017.0	1118.1	.00689	145.2
20	161.2	129.0	1001.0	1130.0	.0133	75.2
15	178.9	146.8	990.4	1137.2	.0195	51.1
10	192.2	160.1	982.6	1142.7	.0255	39.7
5	202.9	170.9	975.9	1146.8	.0314	31.8
Ga'ge Pres.						
0	212.0	180.0	970.4	1150.4	.0373	26.8
5	227.2	195.3	960.6	1155.9	.0491	20.38
10	239.4	207.7	952.5	1160.2	.0607	16.40
15	249.8	218.2	954.5	1163.7	0721	13.87
20	258.8	227.4	939.2	1166.6	.0834	11.99
25	266.8	235.6	933.6	1169.2	.0946	10.57
30	274.1	243.1	928.5	1171.6	.1058	9.47
35	280.6	249.7	923.8	1173.5	.1168	8.56
40	286.7	256.0	919.3	1175.3	.1278	7.82
45	292.4	261.8	915.2	1177.0	.1387	7.20
50	297.7	267.2	911.2	1178.4	.1497	6.68
55	302.6	272.3	907.4	1179.7	.1605	6.23
60	307.3	277.1	903.9	1181.0	.1714	5.83
65	311.8	281.7	900.5	1182.2	.1823	5.49
70	316.0	286.0	897.3	1183.3	.1930	5.18
75	320.1	290.3	894.1	1184.4	.2041	4.91
80	323.9	294.3	891.1	1185.4	.2145	4.66
85	327.6	298.1	888.2	1186.3	.2252	4.44
90	331.2	301.8	885.4	1187.2	.2358	4.24
95	334.6	305.3	882.6	1187.9	.2465	4.05
100	337.9	308.8	880.0	1188.8	.2570	3.89
105	341.1	312.1	877.4	1189.5	.2677	3.735
110	344.2	315.3	874.9	1190.2	.2785	3.592
115	347.2	318.4	872.5	1190.9	.2890	3.460
120	350.1	321.5	870.1	1191.6	.2996	3.338
125	352.9	324.4	867.8	1192.2	.3101	3.226
130	355.6	327.2	865.6	1192.8	.3207	3.118
135	358.3	330.0	863.4	1193.4	.3314	3.018
140	360.8	332.7	861.2	1193.9	.3419	2.925
145	363.4	335.4	859.0	1194.4	.3523	2.839
150	365.9	338.0	857.0	1195.0	.3627	2.758
155	368.4	340.6	854.8	1195.4	.3732	2.680
160	370.7	343.1	852.8	1195.9	.3837	2.606
165	373.0	345.5	850.9	1196.4	.3942	2.537
170	375.3	347.9	848.9	1196.8	.4046	2.472
175	377.5	350.3	847.0	1197.3	.4151	2.410
180	379.7	352.5	845.1	1197.7	.4256	2.350
185	381.8	354.8	843.3	1198.1	.4364	2.294
190	383.9	357.0	841.5	1198.5	.4464	2.240
195	385.9	359.1	839.7	1198.8	.4564	2.190
200	387.9	361.3	838.0	1199.3	.4670	2.141
210	391.8	365.4	834.5	1199.9	.488	2.049
220	395.5	369.3	831.2	1200.5	.508	1.966
230	399.2	373.2	828.0	1201.2	.529	1.889
240	402.6	376.9	824.8	1201.7	.550	1.818
250	406.1	380.6	821.7	1202.3	.570	1.752

box. The amount of CO, CO_2 and free oxygen contained in this sample will determine whether the right quatities of gas and oxygen were properly mixed at the point of ignition.

Stack Gas Analysis—To every boiler user this branch of engine-room work is very important. In fact it is more so than is generally realized. Very few, if any, factories where natural gas is used as fuel are equipped with gas analysis apparatus. The writer does not desire to state that the analyzing of stack gas will show a loss in every case; but where no loss is shown it is a great satisfaction to know that fuel gas is being used with economy.

Sampling Apparatus—A glass tube five-eighth-inch in diameter and about three feet long, drawn down to one-fourth-inch at one end, is inserted in the stack just above the hood. For this purpose a three-quarter-inch hole is drilled in the stack and the space around the glass tube is stopped with putty or wet cotton waste. Prior to taking the sample all openings other than legitimate ones for draft should be carefully closed.

The stack gas must be sucked into the tube by use of a pump or steam jet. When samples are taken infrequently an ordinary double-ended syringe bulb, provided with a hard rubber valve, may be used.

There are many methods that may be devised, but the main thing to bear in mind is to obtain a true sample of the stack gas absolutely free from air.

The principle of making an analysis is the same as in analyzing natural gas by absorbing the different constituents in the stack gas sample one by one, and measuring the decrease in volume caused by such absorption.

The following chemical solutions are used for the absorption process.

For carbon dioxide (carbonic acid), potassium hydrate.

For oxygen, alkaline solution of potassium pyrogallate.

For carbonic oxide, cuprous chloride.

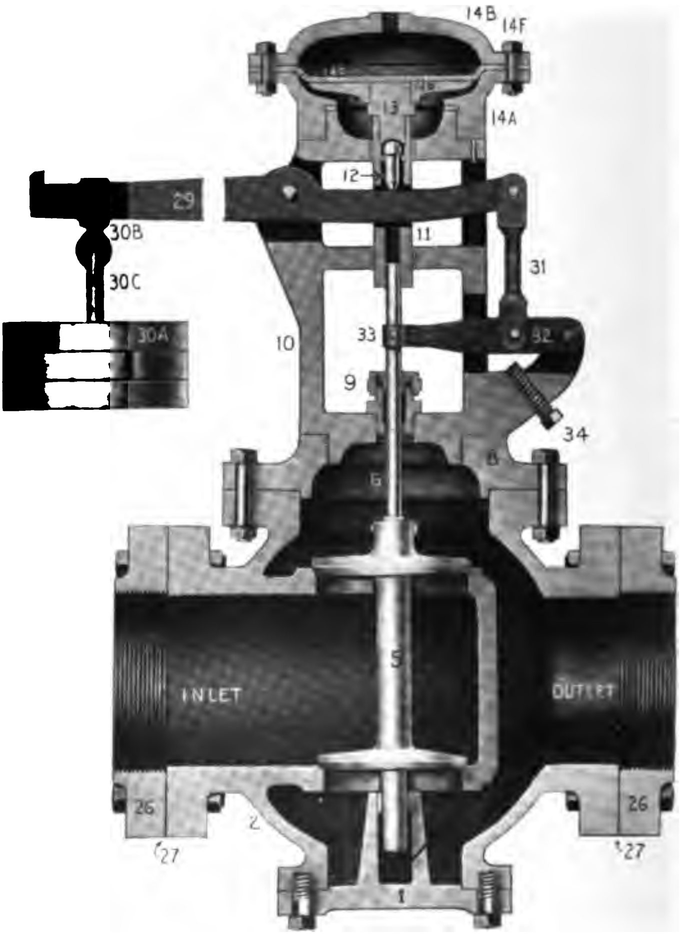


Fig. 208—SECTIONAL VIEW OF BOILER GAS REGULATOR. STEAM CONNECTION IS MADE WITH THE TOP OF DIAPHGRAGM CHAMBER

Fig. 209—CO_2 INDICATOR

After the sample has been subjected to the absorption action of each of the above chemicals and correct deductions made, the residue may consist of nitrogen (the principal constituent), hydrocarbons and hydrogen.

If desired, a sample of the flue gas can be taken—leaving as little water in the apparatus as possible—and sent to a competent chemist for analysis.

Gas Pressure—Pressure should be measured at the burner, not at the meter or regulator. The greater the gas pressure, the greater the velocity of the gas leaving the burner, creating a better vacuum and thereby causing a greater volume of air to enter the mixing chamber, which will increase the capacity of the burner.

Eight-ounce pressure gives the best results, with a working range of from five to twelve ounces.

Results—It is not possible to derive the same boiler efficiency in all gas fields, but assuming that the gas contains 1000 B. t. u. per cubic foot, the boiler or furnace should develop an efficiency of at least seventy per cent. or greater.

TABLE No. 88—CO_2 AND FUEL LOSSES.

When you Know the Percentage of CO_2, you Know the Fuel Loss.

Pct. CO_2	Percentage Preventable Fuel Loss	Pct. CO_2	Percentage Preventable Fuel Loss	Pct. CO_2	Percentage Preventable Fuel Loss
15.	0.0	10.0	5.69	5.0	22.79
14.8	0.148	9.8	6.04	4.8	24.21
14.6	0.305	9.6	6.40	4.6	25.76
14.4	0.470	9.4	6.78	4.4	27.44
14.2	0.635	9.2	7.18	4.2	29.29
14.0	0.808	9.0	7.58	4.0	31.28
13.8	0.990	8.8	8.02	3.8	33.58
13.6	1.17	8.6	8.47	3.6	36.08
13.4	1.36	8.4	8.95	3.4	38.87
13.2	1.54	8.2	9.44	3.2	42.01
13.0	1.75	8.0	9.66	3.0	45.28
12.8	1.95	7.8	10.51	2.8	49.64
12.6	2.16	7.6	11.09	2.6	54.34
12.4	2.38	7.4	11.70	2.4	60.32
12.2	2.60	7.2	12.34	2.2	66.30
12.0	2.84	7.0	13.02	2.0	74.00
11.8	3.08	6.8	13.74	1.8	83.56
11.6	3.33	6.6	14.49	1.6	95.45
11.4	3.59	6.4	15.30	1.4	
11.2	3.86	6.2	16.16	1.2	
11.0	4.13	6.0	17.09	1.0	
10.8	4.43	5.8	18.06	.8	
10.6	4.72	5.6	19.12	.6	
10.4	5.03	5.4	20.25	.4	
10.2	5.35	5.2	21.47	.2	

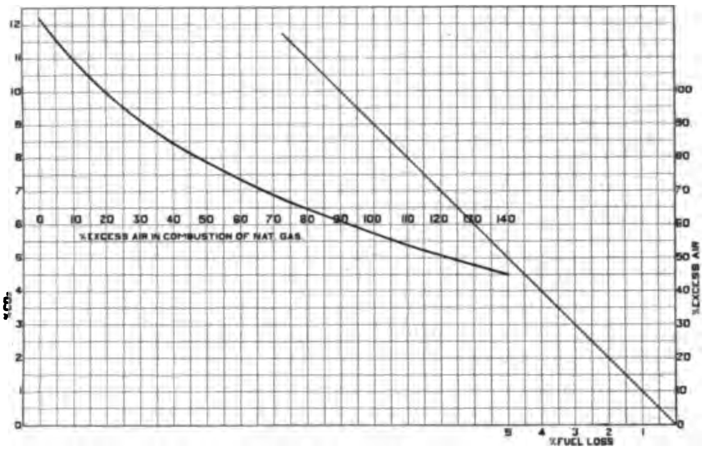


Fig. 210—CHART FOR CALCULATION OF FLUE-GAS ANALYSIS FROM THE ANALYSIS OF NATURAL GAS BURNED

CALCULATION OF FLUE-GAS ANALYSIS FROM THE ANALYSIS OF NATURAL GAS BURNED

Assume a natural gas to have the following analysis:—

Methane (CH_4)	84	per	cent	by	volume
Ethane (C_2H_6)	13	"	"	"	"
Carbon Dioxide (CO_2)	2	"	"	"	"
Nitrogen (N_2)	1	"	"	"	"

The combustion of the hydrocarbons proceeds as per the following equations:—

$$CH_4+2O=CO_2+2H_2O$$
$$2C_2H_6+7O=4CO_2+6H_2O$$

Therefore for the combustion of the natural gas of the above analysis there is required:—

1.680	cu. ft. oxygen	for	0.84	cu. ft. CH_4	yield	0.84	cu. ft. CO_2
0.455	" "	"	0.13	" " C_2H_6	"	0.26	" " "
0.000	" "	"	0.02	" " CO_2	"	0.02	" " "
0.000	" "	"	0.01	" " N_2	"	0.00	" " "
2.135			1.00			1.12	

As air contains 21 per cent. oxygen by volume, 2.135 cu. ft oxygen represent 2.135/.21 or 10.17 cu. ft. air. Therefore each cu. ft. gas burned requires 10.17 cu. ft. air for theoretical combustion. Also, in this combustion there is obtained 1.12 cu. ft. CO_2 and 10.17 x .79 (air contains 79 per cent. nitrogen by volume) or 8.0343 cu. ft. nitrogen.

In the theoretical combustion the flue gas analysis would show

$$\frac{1.12}{1.12 + 8.0343} = 12.23 \text{ per cent } CO_2 \text{ and}$$

$$\frac{8.0343}{1.12 + 8.0343} = 87.77 \text{ per cent } N_2$$

When air is supplied 20 per cent in excess of that needed for a perfect combustion we get in the flue gas:—

$$\frac{1.12}{(10.17 \times .20 \times .21) + (10.17 \times 1.20 \times .79) + 1.12} = 10.01 \text{ per cent } CO_2$$

$$\frac{(10.17 \times .20 \times .21)}{(10.17 \times .20 \times .21) + (10.17 \times 1.20 \times .79) + 1.12} = 3.81 \text{ per cent } O_2$$

$$\frac{(10.17 \times 1.20 \times .79)}{(10.17 \times .20 \times .21 + (10.17 \times 1.20 \times .79) + 1.12} = 86.18 \text{ per cent } N_2$$

In the same manner, for a 40 per cent excess air, the flue-gas analysis would show 8.47 per cent CO_2, 6.47 per cent O_2, and 85.06 per cent N_2. 75 per cent excess air would show 6.67 per cent CO_2, 9.54 per cent O_2, and 83.79 per cent N_2. 100 per cent excess air would show 4.55 per cent CO_2, and 82.33 per cent N_2.

From these data it is possible to plot curves and determine the excess air for each analysis of a flue gas. Then knowing this percentage of excess air, it is possible to calculate the amount of heat lost in heating up this volume of air from the temperature of the boiler room to the stack temperature.

Assuming an average stack temperature of 600 deg. fahr. and a boiler room temperature of 80 deg. fahr., when 20 per

cent excess air is used in combustion (2.034 cu. ft.), the heat lost equals:—

$$2.034 \times .0805 \times 0.24 \times (600-80) = 20.43 \text{ B. t. u.}$$

The United States Weather Bureau reports that for Los Angeles, California the average yearly temperature is 62 deg. fahr. and 70 per cent. relative humidity (equiv. to 0.00064 lb. moisture contained in each cu. ft. of air). To heat this moisture in 2.034 cu. ft. of air from 80—600 deg. fahr. requires:

$$2.034 \times 0.00064 [(1 \times (212-80) + 970 + 0.5 (600-212)] = 1.69 \text{ B. t. u}$$

Therefore the total heat lost equals:—

$$20.43 + 1.69 = 22.12 \text{ B. t. u.}$$

Assuming the natural gas averages 1125 B. t. u. per cu. ft. this loss expressed in percentage becomes $22.12 \div 1125 = 1.97$ per cent.

In the same manner the heat lost in using 40 per cent. excess air is 3.94 per cent. of the fuel; for 75 per cent. excess air. 7.39 per cent. for 100 per cent. excess air, 9.85 per cent. and for 150 per cent. excess air 14.78 per cent.

GAS ENGINES (Section)

Gas engines are divided into two general classes, commonly known as two-cycle and four-cycle.

These terms are derived from the number of strokes of the piston required to complete a cycle, during which time only one impulse is given to the piston.

The two-cycle engine gives one impulse to the piston for each revolution of the crank shaft and is more flexible in speed control than the four-cycle engine which gives but one impulse to the piston for each two revolutions of the crank shaft.

For steady work such as driving a pumping station the four-cycle engine is best suited.

For fluctuating work such as cleaning out wells the two-cycle engine is most desirable.

Ignition is usually effected by allowing the compressed mixture to enter an iron tube, kept at a bright red heat by a Bunsen flame surrounding it. Electric ignition is frequently used, in which case the electric current is generally furnished by a magneto so arranged to generate a maximum current at the proper firing instant.

The proper firing instant varies according to load, speed and quantity of mixture. The length of the hot tube may be varied to suit local conditions.

TABLE No. 89

Average Amount of Natural Gas Required to Operate Gas Engines or for Steam Engines where Natural Gas is used as Fuel Under Boilers, in Cubic Feet per Indicated H. P. per Hour.

Type of Engine	Cubic Feet of Gas per Horse Power per Hour
Large natural gas engine, highest type	9
Ordinary natural gas engine	13
Triple expansion condensing steam engine	16
Double expansion condensing steam engine	20
Single cylinder and cut-off steam engine	40
Ordinary high pressure, without cut-off, steam engine	80
Ordinary oil well pumping steam engine	130

From ten to twelve cubic feet of air are necessary for the complete combustion of one cubic foot of natural gas. The natural gas engine has been most successfully introduced as a source of power throughout the entire gas belt. The first engines were from ten to fifteen horse power, and were used in pumping oil wells. Of late they have also been used to some extent for drilling wells. Many natural gas engines, working up to 2,500 horse power, are in use at this date compressing natural gas, where the original pressure is not sufficient to carry the required quantity to market.

Horse Power of Gas Engines—The horse power of a gas engine is usually rated as the actual power delivered to the belt on average fuel. This power delivered to the belt bears a close relationship to the power developed in the cylinder, and the more excellent the design and construction of the engine the more nearly will these two powers be equal.

Power is developed by compressing a mixed charge of gas and air in the cylinder and then igniting it. The heat produced by the combustion causes the gases to expand and exert a pressure on the piston which drives the latter forward to the end of its stroke when the pressure is released by means of the exhaust valve.

The pressure due to rapid combustion is the same for any size engine provided the compression and mixture are the same and the horse power of the engine depends upon the size of the cylinder.

Various ratings are used to designate the size of an engine but the surest guide to comparative power is to compare the sizes of cylinders.

Size for size a two-cycle engine will develop something less than twice the power of a four-cycle engine.

In buying engines, do not be guided altogether by horse power rating but look well into cylinder sizes to determine whether the engine is large enough to justify its rating.

Size of Gas Supply Pipe—Multiply the horse power of the engine by .03 and add ¾-inch to find the proper size of gas supply pipe.

Exhaust Pipe—The exhaust pipe should be as straight and free from bends as possible, also the outlet should be shielded to prevent rain collecting therein. The diameter of the exhaust pipe should be between one-third and one-quarter of the cylinder diameter.

TABLE No. 90

Length and Diameter of Services for Gas Engines.

Horse Power of Engine	50 Feet of Pipe Diam. In.	100 Feet of Pipe Diam. In.	150 Feet of Pipe Diam. In.	225 Feet of Pipe Diam. In.
5	1	1	1¼	1¼
10	1¼	1½	1½	1½
15	1¼	2	2	2
20	1½	2	2	2
30	1½	2½	2½	2½
40	2	2½	2½	3
50	2½	2½	3	3

Circulating Water—Water must be kept circulating in the jacket of the engine cylinder to cool the walls and make lubrication possible. This requires from four to six gallons per horse power per hour. Where a tank is used its capacity should be such as to allow twenty to forty gallons per horse power.

The water-circulating pipes should be free from bends and the top or return pipe should be one-half-inch larger than the bottom or inlet pipe. The return pipe should enter the tank below the top level of the water therein.

When hard water is used for the jacket, put a handful of ordinary washing soda into the tank about once a month.

COMPARATIVE ACTUAL OPERATING COSTS OF 100 H. P. IN THE VARIOUS PRACTICAL FORMS OF POWER NOW AVAILABLE

Based on a Running Day of 10 Hours; 310 Days per Year; FULL LOAD Continuously for Entire Ten Hours

In making comparisons with his own actual costs of operation, the power user should take the total cost of a single horse power, as given in synopsis below; and, figuring from the basis of the **actual** load his power plant is carrying, cut from, or add to, all the other figures proportionately.

Steam engines are sold at their **indicated** horse power, which is from 10 per cent. to 18 per cent. higher than their brake horse power. Gas engines are sold at **brake** horse power, and a 100 h. p. gas engine has from 10 per cent to 18 per cent greater efficiency than a 100 h. p. steam engine

TABLE No. 91

	Ordinary Steam Engine	Compound Condensing Engine	Electricity
Fuel	1 $3,720.00	2 $2,092.50	3 $6,975.00
Attendance	7 775.00	7 775.00	8 77.50
Oil, waste, cleaning materials	75.00	75.00	50.00
Packing	5.00	5.00	....
Water	11 77.50	387.50	....
Repairs	13 109.50	13 175.50	14 52.50
Depreciation	17 255.50	17 409.50	18 175.00
Interest on investment—6%	219.00	351.00	105.00
Complete actual cost of operation	$5,236.50	$4,271.00	$7,435.00

	Gas Engine Illuminating Gas	Gas Engine Natural Gas	Gas Engine Producer Gas
Fuel	4 $4,216.00	5 $1,116.00	6 $639.37
Attendance	9 155.00	9 155.00	10 258.33
Oil, waste, cleaning materials	75.00	75.00	75.00
Packing	....	....	....
Water	12 46.50	12 46.50	77.50
Repairs	15 75.00	15 75.00	16 85.00
Depreciation	19 187.50	19 187.50	20 187.50
Interest on investment—6%	225.00	225.00	381.00
Complete actual cost of operation	$4,980.00	$1,880.00	$1,703.70

1—Based on 8 lb. coal, at $3 per ton, per B. h. p. hour; covering operation and stand-by consumption.

2—Based on 4½ lb. coal, at $3 per ton, per B. h. p. hour; covering operation and stand-by consumption.

3—1000 watts equal 1 kilowatt; 100 h. p. equals 75 kilowatts; 75 kilowatts at 3c per hour equals $22.50 per day.

4—Based on consumption of 17 cubic feet per B. h. p. hour at 80c per M. equals $13.60 per day.

5—Based on consumption of 12 cubic feet per B. h. p. hour, at 30c per M. equals $3.60 per day.

6—Based on 1.5 anthracite screenings, at $2.50 per ton, per B. h. p. hour, including stand-by losses, equals 1,650 lb. per day.

7—One licensed engineer at $2.50 per day.

8—Average of one hour's attendance per day of man at $2.50.

9—2 hours per day will cover all attendance necessary; licensed engineer not obligatory.

10—One-third of one man's time, at $2.50 per day, will take care of plant.

11—Based on price of 5c per M. gals., which is about same when pumped by condenser pump.

12—3 gals. per B. h. p. per hour. By use of tank same water can be used over and over, and water expenses eliminated.

13—Estimated at 3 per cent. of entire cost of plant per annum, including boiler.

14—Estimated at 3 per cent. of entire cost of plant per annum.

15—Estimated at 2 per cent. of entire cost of plant per annum.

16—$10.00 per annum will more than cover all repairs on producer plant, as same is subject to no stress or strain; 2 per cent. is estimated as repairs on gas-engine portion of plant.

17—Estimated at 7 per cent. of entire cost of plant.

18—Estimated at 10 per cent. of entire cost of plant.

19—Estimated at 3 per cent. of entire cost of plant.

20—$10.00 per annum in repairs will keep producer portion of plant in perpetual good condition, and depreciation is therefore figured on gas engine only.

TABLE No. 92

Synopsis of Above Tables of Actual Operating Costs of 100 Horse Power.

	Comparative annual operating costs of 100 h. p. in proportion to initial cost of plant	Actual annual operating cost of different forms of power per h. p.
Ordinary steam engine	143 per cent.	$52.36
Compound steam engine	73 per cent.	42.71
Electricity	424 per cent.	74.35
Illuminating gas	132 per cent.	49.80
Natural gas	46 per cent.	16.94
Producer gas	24 per cent.	14.90

Compounded steam engine is 29 per cent. cheaper to operate than an ordinary steam engine.

Electricity is 30 per cent. dearer to operate than an ordinary steam engine.

Gas engine (illuminating gas) is 5 per cent. cheaper to operate than an ordinary steam engine.

Gas engine (natural gas) is 68 per cent. cheaper to operate than an ordinary steam engine.

Gas engine (producer gas) is 73 per cent. cheaper to operate than an ordinary steam engine.

Electricity is 43 per cent. dearer to operate than a compound steam engine.

Gas engine (illuminating gas) is 16 per cent. dearer to operate than a compound steam engine.

Gas engine (natural gas) is 61 per cent. cheaper to operate than a compound steam engine.

Gas engine (producer gas) is 65 per cent. cheaper to operate than a compound steam engine.

Gas engine (illuminating gas) is 33 per cent. cheaper to operate than electricity

Gas engine (natural gas) is 77 per cent cheaper to operate than electricity.

Gas engine (producer gas) is 80 per cent cheaper to operate than electricity.

Gas engine (natural gas) is 62 per cent. cheaper to operate than illuminating gas.

Gas engine (producer gas) is 70 per cent. cheaper to operate than illuminating gas.

Gas engine (producer gas) is 12 per cent. cheaper to operate than natural gas.

(Courtesy Bessemer Gas Engine Co.)

Fig. 211

PART SIXTEEN

POWER

Horse Power—The use of the term "horse power," as indicating the measure of an engine's work, came naturally from the fact that the first engines were built to do work that had formerly been performed by horses. John Smeaton, who built atmospheric engines before Bolton and Watt placed their more complete machines upon the market, had valued the work done by a strong horse as being equivalent to lifting a weight of 20,000 pounds one foot high in one minute. When Bolton and Watt began to bid for public favor, they agreed to place their engines "for a value of one-third part of the coals which are saved in its use." They also increased the value of the "horse power" to 33,000 pounds, so that their engines were half again as powerful for their rated power as those of their competitors. In this way they established the value of horse power.

The following are the values of a horse power:

33,000 foot pounds per hour.
550 foot pounds per minute.
2545 thermal units per hour.
42.42 thermal units per minute.

The horse power of a boiler depends upon its capacity for evaporation. The evaporation of thirty pounds of water from 100 deg. fahr. into steam at 70 pounds gauge pressure (equaling 34½ pounds from and at 212 deg. fahr.) is equal to a horse power.

To find the mean effective pressure of a simple steam engine, using steam at an initial pressure of 80 pound gauge, divide the length of cut-off by the total length of the stroke, both in inches, and take the mean effective pressure from the following table:

Cut-off per cent. of stroke....	.10	.15	.20	.25	.30	.35	.40	.45	.50
M. E. P. lb. per sq. in.	18	27	35	42	48	53	57	61	64.

Superheated steam is steam which has a greater temperature than that due to its pressure.

To determine the heating surface in the tubes of any boiler, multiply the number of feet of the tubes by the decimal .523 for 2-inch; .654 for 2½-inch; .785 for 3-inch; .916 for 3½-inch; and by 1.047 for 4-inch.

Steam—Steam is an elastic fluid generated by the action of heat upon water.

Steam, when separated from water, from which it is generated, follows the law of all other gases, expanding $\frac{1}{460}$ of its volume for each additional degree of heat, the pressure remaining the same; and, while the temperature remains the same, the pressure is in inverse proportion to the volume.

The temperature of the steam is equal to that of the water from which it is formed, and its elastic force is equal to the pressure under which it is formed.

Total heat of steam at 212 deg. fahr. is 1150.4 B. t. u.

Latent heat of steam is found by subtracting its sensible heat (called heat of the liquid) from the total heat, and is equal to 970.4 B. t. u. at 212 deg. fahr. or 14.7 lb. atmospheric pressure.

Latent heat of steam is composed of two elements—the heat required to evaporate the water into steam at the same temperature and pressure, and that necessary to do the external work required by the steam to make room for itself against the pressure of the surrounding steam or atmosphere. It is not evidenced by any increase in temperature.

To find the quantity of water required to condense a given quantity of steam, subtract the heat of the liquid at the temperature of the hot well from the total heat of the steam to be condensed. Then divide this difference by the

difference in temperature between the hot well and the injection water, and multiply the quotient by the number of pounds of steam to be condensed. The result will be the weight of injection water required.

Steam Horse Power—The amount of water which a boiler will evaporate at an economical rate in an hour, divided by the above quantity, is its commercial horse power.

A unit of evaporation is the heat required to evaporate a pound of water from and at 212 deg. fahr. and is equal to 970.4 thermal units.

A thermal unit is the amount of heat required to raise a pound of water a fahrenheit degree in temperature at the point of maximum density, namely, 39 deg. fahr.

One thermal unit is equivalent to 778 foot pounds. The horse power of engines varies directly as the product of the piston area, piston speed, and mean effective pressure. Hence with the same M. E. P., the power of engines varies directly as their piston speed, and as the square of the diameter.

To Find Horse Power of a Steam Engine—To find the horse power of a steam engine, multiply the diameter of the piston in inches by itself, and this result by .7854, which will give the area of the piston in square inches. Multiply the area so found by the speed of the piston in feet per minute; or, if the speed is taken in inches, divide the product by 12, after multiplying. (Speed of piston is found by multiplying twice the length of stroke by the number of revolutions per minute.) Multiply speed of piston by the mean effective (average) pressure of steam upon the piston (which can only be determined by applying the indicator), and divide the product by 33,000, which gives the actual horse power.

Directions for Determining the Correct Setting of Engine Valves—First, equalize travel in steam chest by turning eccentric on shaft so throw is extreme one way, measuring the port opening; then turn eccentric extreme travel opposite, measuring port opening the same. If any difference,

TABLE No. 93
TABLE OF AREAS OF CIRCLES

Diam. Inch	Area	Diam. Inch	Area	Diam. Inch	Area	Diam. Inch	Area
1/8	.0123	7¾	47.17	18½	268.80	37½	1104.5
¼	.0491	8	50.27	19	283.53	38	1134.1
3/8	.110	8¼	53.46	19½	298.65	38½	1164.2
½	.196	8½	56.75	20	314.16	39	1194.6
5/8	.307	8¾	60.13	20½	330.06	39½	1225.4
¾	.442	9	63.62	21	346.36	40	1256.6
7/8	.601	9¼	67.20	21½	363.05	40½	1288.2
1	.785	9½	70.88	22	380.13	41	1320.3
1 1/8	.994	9¾	74.66	22½	397.61	41½	1352.7
1¼	1.227	10	78.54	23	415.48	42	1385.4
1 3/8	1.485	10¼	82.52	23½	433.74	42½	1418.6
1½	1.767	10½	86.59	24	452.39	43	1452.2
1 5/8	2.074	10¾	90.76	24½	471.44	43½	1486.2
1¾	2.405	11	95.03	25	490.87	44	1520.5
1 7/8	2.761	11¼	99.40	25½	510.71	44½	1555.3
2	3.142	11½	103.87	26	530.93	45	1590.4
2¼	3.976	11¾	108.43	26½	551.55	45½	1626.0
2½	4.909	12	113.10	27	572.56	46	1661.9
2¾	5.940	12¼	117.86	27½	593.96	46½	1698.2
3	7.069	12½	122.72	28	615.75	47	1734.9
3¼	8.296	12¾	127.68	28½	637.94	47½	1772.1
3½	9.621	13	132.73	29	660.52	48	1809.6
3¾	11.05	13¼	137.89	29½	683.49	48½	1847.5
4	12.57	13½	143.14	30	706.86	49	1885.7
4¼	14.19	13¾	148.49	30½	730.62	49½	1924.4
4½	15.90	14	153.94	31	754.77	50	1963.5
4¾	17.72	14¼	159.48	31½	779.31	50½	2003.0
5	19.64	14½	165.13	32	804.25	51	2042.8
5¼	21.65	14¾	170.87	32½	829.58	51½	2083.1
5½	23.76	15	176.71	33	855.30	52	2123.7
5¾	25.97	15¼	182.65	33½	881.41	52½	2164.8
6	28.27	15½	188.69	34	907.92	53	2206.2
6¼	30.68	15¾	194.83	34½	934.82	53½	2248.0
6½	33.18	16	201.06	35	962.11	54	2290.2
6¾	35.79	16½	213.82	35½	989.80	54½	2332.8
7	38.49	17	226.98	36	1017.88	55	2375.8
7¼	41.28	17½	240.53	36½	1046.3	55½	2419.2
7½	44.18	18	254.47	37	1075.2	56	2463.0

divide it up by lengthening or shortening the valve rod or eccentric rod.

After port openings are equal at both ends, turn crank on dead center; then turn eccentric on shaft so valve opens the port at the end of cylinder where piston is located, about 1/16 opening or lead. Fasten eccentric to shaft; then turn on the other dead center, when opening or lead should be the same.

In determining which way an engine is to run, bear in mind the crank pin always follows the throw of the eccentric.

Electrical Horse Power—The quantity of electricity flowing in a wire per second is measured in units called the ampere. The electrical pressure producing the flow is measured in volts, while the power an electrical current is capable of producing is equal to the product of amperes and volts and is measured in units called the watt. One watt is equal to one ampere multiplied by one volt. A kilowatt is 1000 watts.

The same work can be done with great current strength and low E. M. F. or with small current and high E. M. F. For instance, 100 amperes, times 10 volts, equals 1000 watts; or 10 amperes, times 100 volts, equals 1000 watts.

One electrical horse power equals 746 watts; hence, the electrical work of a dynamo may be expressed:

$$\text{h. p.} = \frac{\text{amperes} \times \text{volts}}{746}$$

The mechanical horse power necessary to drive a dynamo is generally ten to twenty per cent. higher than the electrical horse power yielded by the dynamo.

For Every-day Use in an Engine Room—To find diameter of cylinder for a given power:

Multiply horse power of engine by 33,000. Divide product by the product of cylinder area x steam pressure x piston speed in feet per minute.

Rule for finding contents in cubic feet of a cylinder of any given diameter:—

Multiply the square of diameter in inches by .7854 and this product by length of stroke in inches. Divide last product by 1728, and the result is contents of cylinder in cubic feet.

The diameter of the valve rod should be 1/10 to 1/12 of the cylinder diameter, or from 1/350 to 1/300 of unbalanced area of slide valve. This last is considering the valve as a piston. Steel rods, of course, will bear being made smaller.

Don't depend too much upon the glass gauge, but try the cocks often enough to keep your hand in in telling the height of water by them. If a gauge cock has a tendency to leak, fix it thoroughly; if you do not you will neglect to use it for fear of the work which you may have to stop the leak after using.

Safety valves should be allowed to blow straight out into the room and should not be hitched on to a leading pipe which may allow water to stand on the valve, increasing its weight, or be liable to freeze if the boiler is laid up. When the valve blows into the room it will be known when steam is escaping, whether from leakage or over-pressure.

The economy of an engine should always be rated by the amount of steam or water which it consumes per horse power per hour. The amount of coal burnt per horse power per hour involves the economy of the whole plant, and is not a measure of the performance of the engine taken independently.

Horizontal engines, when practicable, should be run over rather than under, as the thrust will then come downward upon the foundation rather than upon the caps of the boxes and the upper guides.

In calculating horse powers of steam boilers, consider for:—

Tubular boilers, 15 square feet of heating surface, equivalent to 1 horse power.

Portable boilers, 12 square feet of heating surface, equivalent to 1 horse power.

Cylinder boilers, 10 square feet of heating surface, equivalent to 1 horse power.

THE USE OF HIGH-PRESSURE GAS FOR POWER.

In 1917 the writer visited a gas field in southwestern Texas and on the trip noticed a small twin-cylinder steam engine being run by high-pressure gas. The engine furnished power for digging a water "tank." The expanded gas exhausted into the atmosphere.

At a carbon plant located near Monroe, La., the high-pressure gas came into the plant at fifty pounds pressure, and furnished power for a fifty horse power steam engine in lieu of steam, it then was exhausted into the low-pressure system and burned to make carbon. The engine was operated twenty-four hours a day and the only actual loss was from the leakage around the stuffing-boxes on the engine. This of course was a negligible quantity.

Possibilities of Obtaining Electric Power at Regulating Stations on the Edge of Cities—After reading the foregoing article, in which is described using high-pressure gas for power in steam engine and afterward burning the gas to make carbon black, the reader no doubt will appreciate the possibilities in this particular direction.

The average gas man is perfectly familiar with high-pressure regulator installations at the edge of cities. In these stations the gas is reduced from a high or line pressure to possibly an intermediate or belt line pressure, and in some cases directly to a low pressure. The act of reducing the pressure consists of controlling the flow of the gas in the pipe line by checking or retarding it. This retarding or checking means a loss of power.

It is not impossible that a part of the flow of gas could be passed through a specially built engine designed along

the lines of the steam engine and the gas be exhausted from that into the belt line or the low-pressure system. The power could be used to generate electric current. If one will stop to think, the electric lighting load carried by an electric company follows fairly closely the natural-gas load. It is meant by this that the greatest consumption of electric current is during the morning and evening hours, and the greatest load on natural gas is during the morning hours with a slight increase during the evening hours. After midnight there is practically little load on either. It is not the idea of the author to state that the electric load follows the gas load, but to bring out the point that there is a similarity between the two loads as shown on a chart.

In considering this subject one must figure on what is the minimum load during the summer months. This could be taken as a basis to work upon unless the installation of storage batteries was taken into consideration. No doubt batteries would be essential to carry the plant over a breakdown or through a shortage of gas in winter.

At casinghead gasoline plants advantage is taken of the pressure of the residue gas to run a compressor-expander. In this case freezing temperature caused by the expanding gas is a great aid in extracting gasoline from the gas, and afterward the gas is compressed to a high pressure by the power furnished by the expanding gas so that it can be delivered throughout the field for various fuel and power purposes.

The writer believes this subject is worthy of careful consideration where the pressure and volume conditions warrant it.

PART SEVENTEEN

MEASUREMENT OF STEAM BY ORIFICE METER

The great importance of metering steam is due to the cost of generating it, which exceeds the cost of natural gas. The measurement of flow of steam is one of the most important problems facing the plant engineer of today. The turbine and boiler have been materially improved in their design, both as to size and efficiency, but much still depends upon the method of operating these large units. The operating engineer can not get results when working with insufficient knowledge. In particular he needs to know the steam output from boilers, condition of fire, air supply, and steam consumption of various units and operations of the plant. Methods of determining output of prime movers and fuel consumption have been satisfactory for a great number of years, and there is just as great a need for corresponding measurements of the flow of steam and gases to determine the efficiency of boilers and power consuming units.

During the past few years a great many meters of various types have been placed on the market for measuring steam. Some have been fairly successful while others have been a failure. After watching the results obtained from some 50 orifice meters, measuring steam under various conditions, the author is frank to say that the orifice meter appeals to him as the most practical and accurate meter for this character of work.

Whenever the gauge is placed at any distance below the steam line, correction must be made by adjusting the static pressure pen arm or when reading the static pressure, due allowance must be made for the additional pressure caused by the column of water standing in

the gauge lines between the mercury level and the steam line.

In one very large refinery in the west, visited by the author, there were 27 orifice meters in use measuring steam, four measuring gas and two measuring water. Most of these were located on 8-inch lines, and all the gauges for these installations carried a 250 lb. 50-inch differential chart. This standardization of charts for various measuring purposes was of great advantage to the operator.

In regard to the installation, the orifice meter requires but little room and the gauge can be set at any convenient point for reading. Employees are always present when steam is being generated and measured. This is unlike the measurement of high pressure natural gas where the meters are installed at distant points in the field and considerable time is required to give them proper attention. Also in the natural gas business the meters are more or less exposed to weather conditions, while in the steam plant the meter is generally protected, and it is an easy matter to make repairs or adjustments.

Measuring by orifice meter is measuring by weight or impact. An orifice meter installation consists of an orifice placed in the pipe line either between two flanges or in a casting, a recording differential gauge with two pressure connections, one on each side of the orifice, and a static pressure gauge connected with the pipe line. The drop in pressure between the two sides of the orifice is recorded on the chart of the differential gauge in inches of water and the static pressure either recorded on the same chart or a second chart in pounds per square inch. The coefficient for the orifice must be known in order to figure the weight of steam that passed the orifice in one hour (generally coefficients are given for one hour).

TABLE No. 94—COEFFICIENTS FOR THIN ORIFICES.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream. Values of C in $W = C\sqrt{hP}$ where W = Pounds of Steam Per Hour "from and at 212 deg. fahr."

Feed Water Temperature, 62 deg. fahr. Atmospheric Pressure, 14.7 lb.

Diameter of Orifice	Diameter of Pipe Line					
	2 inch	3 inch	4 inch	6 inch	8 inch	10 inch
½	3.090	3.024	3.003	2.985	2.976	2.973
⅝	4.943	4.771	4.716	....	....	....
¾	7.337	6.953	6.836	6.751	6.723	6.706
⅞	10.39	9.613	9.382	....	....	....
1	14.35	12.77	12.37	12.10	12.01	11.97
1⅛	19.50	16.51	15.83	....	....	....
1¼	26.18	20.90	19.79	19.10	18.87	18.77
1⅜	34.96	26.10	24.28	....	....	....
1½	46.13	32.29	29.35	27.84	27.36	27.13
1⅝	....	39.70	35.10	....	....	....
1¾	....	48.44	41.67	38.44	37.54	37.12
1⅞	....	58.90	49.12	....	....	....
2	....	71.55	57.55	51.04	49.47	48.76
2⅛	....	86.41	67.14	....	....	....
2¼	....	103.8	78.04	66.00	63.33	62.15
2⅜	....	....	90.93	....	....	....
2½	....	....	104.8	83.57	79.10	77.27
2⅝	....	....	121.2	....	....	....
2¾	....	....	140.1	104.5	97.01	94.27
2⅞	....	....	161.5	....	....	....
3	....	....	186.1	129.1	117.3	113.2
3¼	....	....	....	158.4	140.3	133.9
3½	....	....	....	193.5	166.6	157.4
3¾	....	....	....	235.2	196.1	183.1
4	....	....	....	285.1	229.8	211.3
4¼	....	....	....	344.6	268.3	242.5
4½	....	....	....	415.4	311.6	277.1
4¾	....	....	....	....	361.9	315.2
5	....	....	....	....	418.2	357.4
5¼	....	....	....	....	484.1	404.4
5½	....	....	....	....	559.2	455.6
5¾	....	....	....	....	643.9	513.6
6	....	....	....	....	741.3	577.2
6¼	....	....	....	....	....	648.1
6½	....	....	....	....	....	727.4
6¾	....	....	....	....	....	815.6
7	....	....	....	....	....	914.3
7¼	....	....	....	....	....	1023.
7½	....	....	....	....	....	1143.

The formula to be applied to the chart readings is the same as for gas. The quantity or weight (W) of steam flowing through the orifice expressed in pounds "from and at 212 deg. fahr." from an average feed water temperature of 62 deg. fahr. equals hourly coefficient (C) multiplied by $\sqrt{hP}$

h = differential pressure expressed in inches of water.

P = absolute pressure (atmospheric pressure plus gauge pressure).

The hourly coefficient for any sized orifice is supplied by the factory. Table No. 94 gives hourly coefficients for this formula for various sized orifices and pipes when pressures are taken 2½ diameters upstream and 8 diameters downstream.

The formula $\sqrt{hP}$ has been worked out for all differential pressures between one to fifty inches differential, and from twenty-nine inches of mercury vacuum up to 500 lb. static pressure, and is given in our Hand Book entitled "Measurement of Gas by Orifice Meter."

Example—Average steam pressure, 100 lb.; Differential head, 36 inches. Size of orifice, 6 inches x 2 inches. In Table No. 94, under 6 inch pipe for 2 inch orifice, the hourly coefficient is 51.04 for pressures taken 2½ diameters upstream and 8 diameters downstream. Therefore W = $51.04 \sqrt{36\,(100+14.7)} = 51.04 \times 6.000 \times 10.71 = 3280$ lbs.

The following corrections in results obtained by the formula can be applied as the formula expresses the result in pounds of steam "from and at 212 deg." with feed water at temperature of 62 deg. fahr. converted into dry saturated steam at pressure indicated by the gauge. For each ten degrees of temperature of water above 62 degrees, one per cent. should be deducted from the result. For each ten degrees below 62 deg. fahr. one per cent. should be added. The following table gives percentage to be deducted from the result where steam is not entirely composed of dry saturated vapor.

TABLE No. 95

Percentage of Moisture	Correction in Per Cent Deduction	Percentage of Moisture	Correction in Per Cent Deduction
5	1.27	20	5.56
10	2.63	25	7.15
15	4.05	30	8.84

EXAMPLE—If the steam measured at 100 lb. gauge pressure in example contained 20 per cent moisture, the deduction would be 5.56 per cent of 3280, or 182 lb., leaving a net result of 3098 lb. In case the steam is superheated, a subtraction must be made for various amounts of superheat as follows:

TABLE No. 96

Degrees of Superheat, Fahr.	Percentage to be Deducted	Degrees of Superheat, Fahr.	Percentage to be Deducted
20 deg.	0.65	200	4.85
50	1.50	250	5.70
100	2.80	300	6.30
150	3.90	400	7.10
...	....	500	7.75

The steam as measured usually contains the same percentage of moisture or amount of superheat and therefore the correction can be either applied to the hourly coefficient for the orifice or to the result.

TABLE No. 97—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Measuring Flow of Steam at Different Pressures, using a 50-inch Differential Chart. For a 2 inch Orifice Meter.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
½	55 165	74 226	88 264	101 303	113 340
⅝	88 264	118 350	141 420	162 490	180 540
¾	131 390	175 530	210 630	239 720	270 810
⅞	185 560	248 740	298 890	340 1,020	380 1,140
1	256 770	340 1,120	450 1,230	470 1,410	520 1.560
1⅛	350 1,050	460 1,380	560 1,680	640 1,920	710 2,130
1¼	470 1,410	620 1,860	750 2,250	840 2,520	950 2,850
1⅜	640 1,920	830 2,490	1,000 3,000	1,130 3,390	1,260 3,780
1½	830 2,490	1,110 3,330	1,330 3,990	1,520 4,560	1,680 5,040

TABLE No. 98—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Measuring Flowing Steam at Different Pressures, using a 50 inch Differential Chart. For a 3 inch Orifice Meter.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
½	54 162	72 216	86 258	99 297	110 330
⅝	85 255	114 340	137 410	156 470	174 520
¾	124 370	166 500	199 600	227 680	252 760
⅞	173 520	230 690	277 830	320 960	350 1,050
1	228 680	300 900	370 1,110	420 1,260	460 1,380
1⅛	295 890	390 1,170	460 1,440	540 1,620	600 1,800
1¼	370 1,410	500 1,500	600 1,800	680 2,040	660 1,980
1⅜	460 1,380	620 1,860	750 2,250	850 2,550	950 2,850
1½	570 1,710	770 2,310	920 2,760	1,050 3,200	1,170 3,500
1⅝	710 2,130	990 2,820	1,130 3,900	1,290 3,900	1,440 4,300
1¾	860 2,580	1,150 3,500	1,380 4,100	1,580 4,700	1,760 5,300
1⅞	1,050 3,200	1,400 4,200	1,680 5,000	1,910 5,700	2,130 6,400
2	1,270 3,800	1,700 5,100	2,030 6,100	2,320 7,000	2,570 7,700
2⅛	1,530 4,600	2,050 6,200	2,460 7,400	2,800 8,400	3,120 9,400
2¼	1,870 5,600	2,490 7,500	2,990 9,000	3,400 10,200	3,800 11,400

TABLE No. 99—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Measuring Flow of Steam at Different Pressures, using a 50 inch Differential Chart. For a 4 inch Orifice Meter.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
½	54 162	72 216	86 258	98 294	109 330
⅝	105 320	112 340	135 400	154 460	171 510
¾	122 370	163 490	196 590	223 670	249 750
⅞	167 400	224 670	269 810	310 930	340 1,020
1	221 660	295 890	350 1,050	400 1,200	450 1,350
1⅛	282 850	380 1,140	450 1,350	520 1,600	580 1,740
1¼	350 1,050	470 1,410	560 1,680	650 2,000	720 2,160
1⅜	440 1,320	580 1,740	700 2,100	790 2,900	880 2,640
1½	520 1,560	700 2,100	840 2,520	960 2,900	1,070 3,200
1¾	750 2,250	990 2,970	1,200 3,600	1,350 4,100	1,430 4,300
2	940 2,760	1,360 4,100	1,640 4,900	1,870 5,600	2,080 6,200
2¼	1,390 4,200	1,850 5,600	2,230 6,700	2,530 7,600	2,830 8,500
2½	1,860 5,600	2,490 7,500	2,980 8,900	3,400 10,200	3,800 11,400
2¾	2,490 7,500	3,300 9,900	4,000 12,000	4,500 13,550	5,100 15,300
3	3,300 9,900	4,400 13,200	5,300 15,900	6,100 18,300	6,700 20,100

TABLE No. 100—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Measuring Flow of Steam at Different Pressures, using a 50 inch Differential Chart. For a 6 inch Orifice Meter.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
1	216 650	288 860	350 1,050	400 1,200	440 1,320
1¼	340 1,020	460 1,380	550 1,650	630 1,890	700 2,100
1½	500 1,500	660 1,980	800 2,400	910 2,730	1,010 3,000
1¾	690 2,070	910 2,730	1,100 3,300	1,260 3,800	1,390 4,200
2	910 2,730	1,220 3,700	1,480 4,400	1,670 5,000	1,850 5,600
2¼	1,180 3,500	1,580 4,700	1,890 5,700	2,150 6,500	2,400 7,200
2½	1,490 4,500	2,000 6,000	2,390 7,200	2,730 8,200	3,000 9,000
2¾	1,860 5,600	2,490 7,500	3,000 9,000	3,400 10,200	3,800 11,400
3	2,300 6,900	3,100 9,300	3,700 11,100	4,200 12,600	4,700 14,100
3¼	2,820 8,500	3,800 11,400	4,500 13,500	3,200 15,600	5,700 17,100
3½	3,500 10,500	4,600 13,800	5,500 16,500	6,400 19,200	7,000 21,000
3¾	4,200 12,600	5,600 16,800	6,700 20,100	7,700 23,100	8,500 25,500
4	5,100 15,300	6,800 20,400	8,100 24,300	9,300 27,900	10,300 31,000
4¼	6,100 18,300	8,200 24,600	9,800 29,400	11,200 34,000	12,500 38,000
4½	7,500 22,500	10,000 30,000	12,000 36,000	13,600 41,000	15,200 46,000

TABLE No. 101—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Measuring Flow of Steam at Different Pressures, using a 50 inch Differential Chart. For an 8 inch Orifice Meter.

Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
1	213 640	286 860	340 1,020	400 1,200	440 1,320
1¼	340 1,020	450 1,350	540 1,620	620 1,860	680 2,040
1½	490 1,470	650 1,950	790 2,370	890 2,670	1,000 3,000
1¾	670 2,010	890 2,670	1,080 3,200	1,220 3,700	1,360 4,100
2	880 2,640	1,180 3,500	1,410 4,200	1,610 4,800	1,790 5,400
2¼	1,130 3,400	1,510 4,500	1,820 5,500	2,060 6,200	2,300 6,900
2½	1,410 4,200	1,890 5,700	2,260 6,800	2,580 7,700	2,880 8,600
2¾	1,730 5,200	2,310 4,900	2,770 8,300	3,170 9,500	3,500 10,500
3	2,090 6,300	2,800 8,400	3,400 10,200	3,830 11,500	4,300 12,900
3½	2,970 8,900	3,900 11,700	4,800 14,400	5,500 16,500	6,100 18,300
4	4,000 12,000	5,500 16,500	6,500 19,500	7,500 22,500	8,400 25,000
4½	5,600 16,800	7,400 22,200	8,900 26,700	10,100 30,000	11,300 34,000
5	7,500 22,500	10,000 30,000	12,000 36,000	13,600 41,000	15,200 46,000
5½	9,900 29,700	13,200 40,000	16,000 48,000	18,600 54,000	20,200 61,000
6	13,200 40,000	17,700 53,000	21,200 64,000	24,200 73,000	27,000 81,000

TABLE No. 102—Minimum and Maximum Capacity per Hour of the Various Sizes of Thin Plate Orifices Maesuring Flow of Steam at Different Pressures, using a 50 inch Differential Chart. For a 10 inch Orifice Meter.

**Pressures Taken 2½ Diameters Upstream and 8 Diameters Downstream.
All Capacities Given in Pounds of Steam "From and At 212 deg. fahr."
Feed Water Temperature, 62 deg. fahr.**

Diam. of Orifice in Inches	Gauge Pressure in Pounds				
	50	100	150	200	250
1¾	660 1,980	880 2,640	1,070 3,200	1,210 3,600	1,340 4,000
2	870 2,610	1,160 3,500	1,390 4,200	1,590 4,800	1,770 5,300
2¼	1,100 3,300	1,480 4,400	1,780 5,300	2,030 6,100	2,250 6,800
2½	1,380 4,100	1,840 5,500	2,210 6,600	2,520 7,600	2,800 8,400
2¾	1,690 5,100	2,250 6,800	2,700 8,100	3,100 9,300	3,400 10,200
3	2,010 6,000	2,700 8,100	3,200 9,600	3,700 11,100	4,100 12,300
3½	2,810 8,400	3,700 11,100	4,500 13,500	5,200 16,200	5,800 17,400
4	3,700 11,100	5,100 15,300	6,100 18,300	7,000 21,000	7,700 23,100
4½	5,000 15,000	6,600 19,800	8,000 24,000	9,000 27,000	10,000 30,000
5	6,500 19,500	8,600 25,800	10,200 31,000	11,600 35,000	13,000 39,000
5½	8,200 24,600	10,900 33,000	13,100 39,000	15,000 45,000	16,600 50,000
6	10,400 31,000	13,800 41,000	16,600 50,000	18,900 57,000	21,000 63,000
6½	13,100 39,000	17,500 53,000	20,700 62,000	23,800 71,000	26,600 80,000
7	16,400 49,000	21,800 63,000	26,300 79,000	30,000 90,000	33,000 99,000
7½	20,700 62,000	27,600 83,000	33,000 99,000	38,000 114,000	42,000 126,000

TABLE No. 103—To Determine the Proper Size of Orifice and Orifice Meter to Measure Different Quantities of Steam per Hour in Pounds, from and at 212 deg. fahr.

Atmospheric Pressure Base, 14.7 lb. Feed Water Temperature, 62 deg. fahr.

Pounds Per Hour	2 Inch Meter — Gauge Pressure in Pounds				3 Inch Meter — Gauge Pressure in Pounds				4 Inch Meter — Gauge Pressure in Pounds			
	50	100	150	250	50	100	150	250	50	100	150	250
200	⅝	⅝	½	½	⅝	⅝	½	½	⅝	⅝	½	½
300	¾	⅝	⅝	⅝	¾	¾	⅝	⅝	¾	¾	⅝	⅝
400	⅞	¾	¾	⅝	⅞	¾	¾	⅝	⅞	⅞	¾	⅝
600	1	1	⅞	¾	1⅛	1	⅞	¾	1⅛	1	⅞	¾
800	1⅛	1	1	⅞	1¼	1⅛	1	⅞	1¼	1⅛	1	⅞
1,000	1¼	1⅛	1⅛	1	1⅜	1¼	1⅛	1	1⅜	1¼	1⅛	1
1,500	1⅜	1¼	1¼	1⅛	1⅝	1½	1⅜	1¼	1¾	1½	1⅜	1¼
2,000	1½	1⅜	1⅜	1¼	1⅞	1⅝	1½	1⅜	2	1¾	1⅝	1½
3,000	....	....	1½	1⅜	2⅛	1⅞	1¾	1⅝	2¼	2	1⅞	1¾
4,000	....	....	....	....	2¼	2⅛	2	1⅞	2½	2¼	2	1⅞
6,000	....	....	....	....	....	....	2¼	2⅛	3	2¾	2½	2¼
8,000	....	....	....	....	....	....	....	2¼	....	3	2¾	2½
10,000	....	....	....	....	....	....	....	....	....	....	3	2¾

Pounds Per Hour	6 Inch Meter — Gauge Pressure in Pounds				8 Inch Meter — Gauge Pressure in Pounds				10 Inch Meter — Gauge Pressure in Pounds			
	50	100	150	250	50	100	150	250	50	100	150	250
600	1¼	1	1	¾	1¼	1	1	¾	1¼	1	....	....
800	1¼	1¼	1	1	1¼	1¼	1	1	1½	1¼	1	1
1,000	1½	1¼	1¼	1	1½	1¼	1¼	1	1½	1¼	1¼	1
1,500	1¾	1½	1½	1¼	1¾	1½	1½	1¼	1¾	1½	1½	1¼
2,000	2	1¾	1½	1½	2	1¾	1¾	1½	2	1¾	1¾	1½
3,000	2½	2¼	2	1¾	2½	2¼	2	1¾	2½	2¼	2	1¾
4,000	2¾	2½	2¼	2	2¾	2½	2¼	2	3	2½	2¼	2
6,000	3¼	3	2¾	2½	3½	3	2¾	2½	3½	3	2¾	2½
8,000	3¾	3¼	3	2¾	4	3½	3	2¾	4	3½	3½	3
10,000	4	3½	3¼	3	4½	4	3½	3	4½	4	3½	3½
15,000	4½	4	3¾	3½	5	4½	4	4	5½	4½	4½	4
20,000	....	4½	4¼	4	5½	5	4½	4½	6	5	5	4½
30,000	....	....	4½	4½	6	5½	5½	5	6½	6	5½	5
40,000	....	....	....	....	....	6	6	5½	7½	6½	6½	6
60,000	....	....	....	....	....	....	....	6	....	7½	7	6½
80,000	....	....	....	....	....	....	....	....	....	....	....	7½

PART EIGHTEEN

THE CARBON BLACK INDUSTRY

Carbon black is a pure, flocculent form of carbon, manufactured from natural gas. It is made by burning gas under very low pressure in a low flame. Not enough air is admitted to produce complete combustion, with the result that the unconsumed carbon is deposited on a roller or plate, from which it is removed by an automatic system of scrapers and conveyors, and bolted and packed by special machinery.

When first scraped from the plates, carbon black is so light that 30 pounds will fill a sugar barrel. When it is considered that the specific gravity of carbon black is about 1.7 (that is, very much heavier than water), it is perceived that 95 per cent of the bulk of black as it comes from the plates is air, and the problem of packing is to separate this black from the air so far as is commercially feasible.

The first carbon black made and sold in this country in a commercial way seems to have been produced in the year 1864 by J. K. Wright, of Philadelphia, Pa., for use in the manufacture of printing ink. This industry is, therefore, a comparatively new one in this country, and it certainly never attained any great importance abroad, although it is not possible to state when carbon black was first made in other countries. Mr. Wright revolved sheet-iron cylinders over jets of artificial gas, and the black was removed from the cylinders by stationary scrapers. This process was used by other ink makers also, and a very glossy, high-priced ink, of intense color, was obtained.

It originated in the great growth of the publication of books and newspapers in the United States, requiring an abundant supply of carbon black which would produce, at a moderate cost, ink adapted to fast presswork.

Fig. 212- CARBON BLACK PLANT IN THE MONROE, LA., GAS FIELD

Carbon black, thus made from natural gas, has been manufactured on a large scale in West Virginia and other states for at least thirty years, and is a well-known staple commodity of which many million pounds are sold annually.

At present it is manufactured in West Virginia, Louisiana, Pennsylvania, Oklahoma, and Wyoming. Up to now the largest production comes from West Virginia, where there are twenty-seven factories in operation. In Louisiana there are eight factories, with more under construction.

It is used for the following purposes: (1) Printer's ink; (2) automobile tires, both pneumatic and solid; (3) black and gray paints for ships and structural iron; (4) carbon paper; (5) typewriter ribbons; (6) phonograph records; (7) tarpaulins; (8) carriage cloth; (9) black leather; (10) paper; (11) bookbinders' board; (12) shoe polish; (13) stove polish; (14) electrical compositions; (15) cameras; (16) crayons..

A form of black is also made by burning tar oils or creosote oils. This is called "lamp black."

Another form of black is made from the burning of animal bone. This is called "bone black."

These blacks are quite different in their properties and uses from black made from natural gas, and cannot be employed in its place, except to a very limited extent.

Carbon black, or any black possessing the same properties or adapted to the same variety of uses, cannot be commercially manufactured from any other material than natural gas.

Theoretically, it might be made from artificial illuminating gas, but this would be utterly impossible as a commercial operation on account of the low yield and the prohibitive cost.

Is the Manufacture of Carbon Black a Waste of Natural Gas? — After making a careful study of the production and

Fig. 213. Burning Buildings Showing Gas Main and Connections

ultimate use of carbon black, the author is frank to say that it is not a waste of natural gas.

The first manufacturers of carbon black endeavored to keep the details of their business secret and quite commonly gave wrong figures to the public which resulted in the public gaining the impression that it was a wasteful enterprise. Nothing was done to enlighten the people regarding the uses of carbon black. When it required but 750 cu. ft. of gas (of .76 gravity) to make one pound of carbon black, the manufacturers would let it be known that it required from, 1500 to 5000 cu. ft. of gas. Their intentions were to keep the number of manufacturers down to as low a number as possible, hence less competition. The result was that the business soon attained a reputation of being a wasteful use of natural gas and in some cases state legislative bodies passed laws restricting the manufacture of carbon black. No doubt these same laws were printed with ink made from carbon black.

There is no known chemical or mineral that can be substituted in the place of carbon black in the manufacture of ink, especially when the ink is used on high-speed newspaper presses. Local Chamber of Commerce organizations would agitate in the local papers against the frightful waste of natural gas in the manufacture of carbon black, and their articles would be printed with ink made with carbon black. Carbon black is just as essential to the country as gasoline, which likewise is made from natural gas, and should be considered on a par with it.

The use of carbon black in the manufacture of automobile and truck tires, both pneumatic and solid, opened a new and highly important market for carbon. In this particular use of carbon it not only can be truthfully said that it conserves rubber by lengthening the life of the tires, but that it is utilizing carbon for a very practical purpose.

Carbon black factories are seldom located near any large market for natural gas. They are generally located near the source of supply which means short pipe lines and low line loss from leakage. While the line leakage to a carbon black plant may be two or three per cent., the author is familiar with some cities where a line loss or leakage exists of over forty per cent., which is partially caused by electrolysis, and never can be reduced till the municipality passes ordinances that will compel the electric railway company to properly bond their rails and install returns to the power plant to eliminate all stray current from the gas lines.

It is true that there is a considerable loss of carbon in the smoke which ascends day and night to a very great height in the atmosphere and can sometimes be seen at a distance of 18 miles, but this consists of lampblack rather than carbon black and would probably only sell for 2 or 3 cents a pound if it could be collected, and the task of collecting even one-half of it would probably be much more expensive than the whole maintenance of the factory and its fuel supply.

While the carbon black manufacture may be criticized for the waste of natural gas, the domestic consumer of natural gas can also be criticized on the same subject. In the chart, "Home Wastes of Natural Gas," published by the Department of Home Economics of Ohio State University the loss in cooking with gas at 4 to 5 ounces pressure is 87 per cent.

Location of Plant—The main point to consider in locating a plant, outside of the proximity to the supply of natural gas and railroad facilities, is to locate it in a depression or gully where it will be least effected by the prevailing winds.

The burning of the gas requires a certain amount of draft, but the flames must be protected from all unnecessary drafts and especially from high winds, otherwise the losses would be entirely too large. Carbon black is very light

and under the most ideal conditions a large percentage is carried off by the burnt gases and is lost.

Description of Plant—A carbon black plant generally consists of twenty to thirty burning buildings, a bolting and packing building, power plant and necessary warehouse for storage of the finished product.

The capacity of a thirty-building plant is dependent upon the constituents in the gas, as the greater the percentage of heavy hydrocarbons in the gas the greater the yield of carbon from 1000 cu. ft. of gas. At one thirty-building plant the writer visited, the production was approximately 4500 lb. per day. This plant was burning natural gas of about 0.61 specific gravity, hence very low in heavy hydrocarbons. This plant consumed during the twenty-four hours about five million cubic feet of gas and made one pound of carbon from 1100 to 1200 cubic feet of gas.

In West Virginia the production of carbon from a similar sized plant with much heavier gas—.76 specific gravity—the production of carbon would run over 6000 lb. per day from the same amount of gas. In other words with this gravity gas it would require from 750 to 800 cu. ft. of gas to make one pound of carbon black.

Burning Buildings—The burning buildings are constructed entirely of sheet iron, size 8 ft. by 2½ ft., angle iron, and plenty of common wire bolts and rivets to fasten the sheet iron on to the frame.

Each building is about 114 feet long and 14 feet wide with 8-foot sides and 12 feet at the peak. Openings are left in the peak for the escape of burnt gases and smoke.

The buildings are arranged in the manner shown in Fig. 214 so that power can be distributed to each building through one shaft running from the power house between the ends of burning buildings. Power is used to operate the channel iron or collecting plates back and forth to scrape off

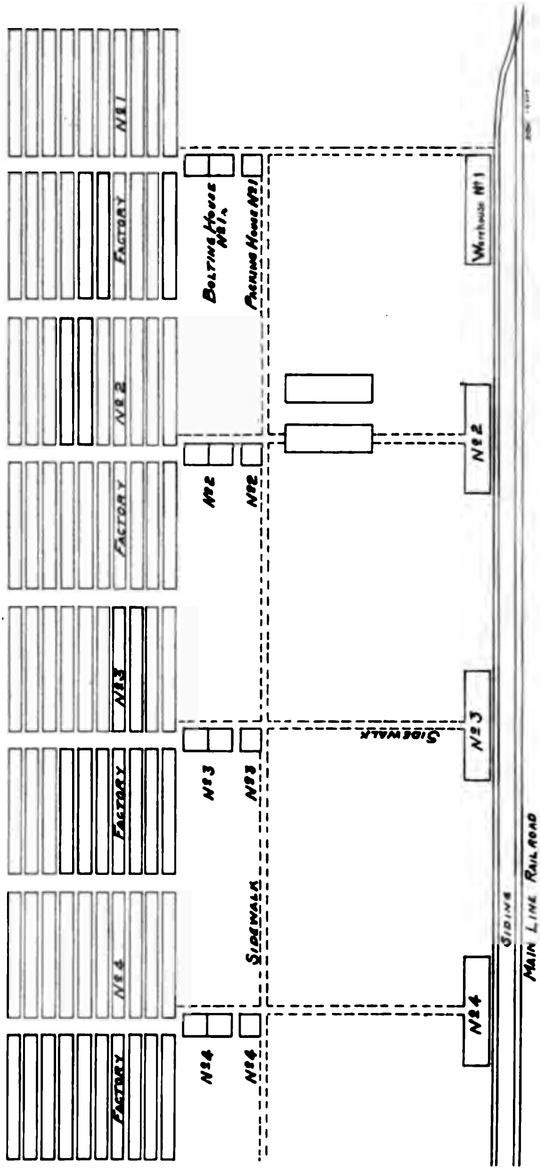


Fig. 214—GENERAL PLAN OF A CARBON BLACK PLANT

the carbon and to turn a worm in the pipe into which the carbon falls from the hoppers (see Fig. 220 on page 641) to convey the carbon from the burners to the bolting and packing building.

Fig. 215—VIEW INSIDE A BURNING BUILDING

Power—It is common practice for carbon black manufacturers to use a steam engine with high-pressure gas as power, then to exhaust the expanded gas into the low-pressure main just back of the gasometer. This furnishes continual

power at no expense other than lubricating oil. A thirty horse power engine is about the right size for a thirty-building plant. The pressure of gas entering the cylinder ranges from fifty to one hundred pounds or about the same as steam. The gas is exhausted into the main at a low pressure.

On account of liability of the cylinders frosting and interfering with the lubrication of the piston, the gas is first run through a coil consisting of about 150 feet of two-inch pipe. laid in the "burning" building nearest to the engine, where the gas is heated and enters the engine cylinder. considerably above the atmospheric temperature, and all liability of frosting in the cylinder is eliminated.

The discharge line is two-inch, connecting with the main line which is generally an eight-inch line The pressure in the main is about one or two inches of water pressure.

Burners or Tips—The gas burners in each burning building are divided into sections—from nineteen to twenty-six varying with different companies. Each section contains eight burners carrying ten lava tips. The burners are made of one-inch pipe and the lava tips are inserted by hand into a hole drilled to fit. To make the common grade of carbon black a twelve-foot tip is used. This tip is commonly used for lighting where artificial gas is sold, except the brass tube or holder is not required, as the lava tip is placed directly in the hole drilled in the pipe. (See Fig. 216).

Fig. 216—LAVA TIPS

The greatest yield of carbon is obtained from a low pressure of about 0.8 of an inch water pressure, which gives a "lazy" flame.

Operation of Plant—A carbon black plant is run twenty-four hours a day and seven days a week. Only a small force is required to operate it. The force consists of a superintendent, one night foreman, and a few packers or helpers. The superintendent acts as the day foreman and generally lives near the plant where he can be called during the night in case anything happens. For a thirty-building plant a force of about eight to ten men is required.

Gas Pressure—The gas is piped to the plant at a high pressure, and is reduced by a regulator to about fifty pounds on the plant property. This pressure is sufficient to run a thirty horse power steam engine of the Atlas type, after which the exhaust from the engine is piped directly into a ten-foot gasometer where the pressure is about one or two inches of water pressure. The amount of gas necessary to run the engine is very small, consequently the main volume of gas is reduced in pressure by a low-pressure regulator to about two or three inches of water pressure before flow into the gasometer. From this it is distributed to the various burning buildings and is burned at a very low pressure of 0.8 of an inch water pressure.

Amount of Gas Necessary to Make one Pound of Carbon Black—This varies according to the quality of the gas. The greater the percentage of heavy hydrocarbons in the gas the less the number of cubic feet of gas necessary to make one pound of carbon.

In West Virginia, where the gas is high in gravity and carries a large percentage of the heavy hydrocarbons, it requires from 750 to 800 cu. ft. of gas to make one pound, and in Louisiana where the gas is dry, it requires 1000 to 1200 cu ft. In the latter case, the gas is mainly of a very high pressure in the wells and no doubt will increase in gravity as the pressure is reduced in future years. It is a well-known fact that the lower the rock pressure of a field, the higher the percentage of heavy hydrocarbons in the gas.

Bolting—After the carbon is scraped from the channel irons or collecting plates it falls down through a hopper or funnel into the carrying pipe. This carrying pipe is an eight-inch conveyor pipe running the full length of each burning building and carries a constantly revolving worm which forces the carbon toward the end of the building where it falls into another but larger size conveyor pipe, likewise carrying a constantly revolving worm which forces the carbon to the bolting or sifting house. Hence it falls on to a belt conveyer, where it is carried up to a height of ten or twelve

Fig. 217—BOLTERS OR SIFTERS

feet, where it falls into the first revolving bolter. This first bolter contains a screen of eight meshes to the inch and separates the hard particles, dirt or scale. The screened carbon then falls out into a second conveyer and is carried up and dropped into a second bolter where a fifty mesh to the inch screen is used. After passing through the second bolter it is carried to a third bolter with a sixty mesh to the inch screen. After being screened in the third bolter it is

conveyed to the bin on the second floor of the building where it is kept until it passes through the automatic packers below into the sacks ready for boxing for shipment.

Packing—Carbon black is packed in 12½ lb. sacks which are about the size of a fifty-pound flour sack, and which in

Fig. 218—AUTOMATIC PACKERS

turn are packed in boxes or cases for shipment. The boxes for shipment are 30 in. x 34-¾ in. x 23 in. and will hold fifteen sacks or 187.5 pounds. For foreign shipment the boxes are bound with steel straps.

Testing Carbon—There are several grades of carbon made, all of which are more or less dependent upon the size of tips and the system used in collecting it.

To test the carbon black, mix a little with some varnish and spread the mixture on a piece of common window glass. When testing a high grade beside a common grade, the difference will be easily detected by the eye. The common grade will appear brownish in color as compared to the color of the high grade.

Principal Use of Carbon Black—Prior to the war the main use of carbon black was for printers' ink, both in this country and abroad. The use of carbon black in the making of automobile tires only began following the shutting off of the importation of oxide of zinc from Germany at the beginning of the war. Oxide of zinc, which was white, was used to coat the bearing surface of automobile tires. After the war started, the tire manufacturers discovered the great advantages in using carbon black in the manufacture of tires and from that time on the carbon black business grew very rapidly. The tire makers now use more carbon black than the printers. While it is possible to manufacture tires without carbon black, it is questionable whether the manufacturer will go back to the use of oxide of zinc.

Carbon Black and Printers' Ink—First in importance among the uses of carbon black is the manufacture of printing inks, particularly those with which our daily and weekly newspapers, journals and magazines are printed. The printing-ink manufacturers of the United States require and use annually about ten million pounds of carbon black made from natural gas.

Practically all the daily newspapers of the large cities require an ink that will dry rapidly and permit the press to be run at high speed. No substitute has been found that can be utilized in the place of carbon as a constituent of

printers' ink and give the same color, which is least injurious to the eyes, and at the same time permit the presses to be run fast resulting in the morning paper being sold for two or three cents.

One pound of carbon black, thus mixed with eight pounds of oil and other chemicals, produces enough ink to print two thousand, two hundred and fifty copies of a sixteen-page newspaper of ordinary size, or ninety copies of a three-hundred-page octavo book.

Carbon black is therefore the vehicle or medium by which the wide and general dissemination of news and instruction through the United States is at present accomplished.

Ink made from carbon black is also used in large quantities in the manifold activities of the United States Government Printing Office.

The ink used in printing the newspapers and other publications of the country is obviously just as necessary to their circulation as the type or press by which they are printed, the paper on which the printing is done, or the mails by which they are distributed.

What applies to newspapers also applies to books, government bulletins, records, legal documents, magazines, catalogues and practically all printed matter.

TABLE No. 104

Formula for the Manufacture of Printing Ink In Which Carbon Black is Used.

Carbon black	10 to 15 per cent.
Linseed Oil Varnish	5 to 60 " "
Rosin Oil Varnish	5 to 85 " "
Prussian Blue	1 to 5 " "
Lead Resinate	2 to 5 " "
Manganese Borate	2 to 4 " "
Rosin Soap	2 to 7 " "

The exact proportions of the above ingredients depend on the condition of use, *i. e.*, paper, speed of press, quality of raw materials and selling price. At present, the only

way of determining the definite proportions is by experience, conditions and materials involved.

Carbon Black and Automobile Tires—Since 1914 an enormous new demand for carbon black has arisen in connection with the manufacture of automobile tires. It has been discovered that by the use of carbon black in the rubber compound a tire is produced which is more resilient, lasts longer, gives better traction, and is less liable to blow out from overheating.

How much importance was attached to this discovery is shown by the fact that one well-known tire company is reputed to have spent upwards of $1,000,000 in advertising "black tread" tires.

Carbon black in large quantities is now being sold to fifty-three tire manufacturers, including such leading concerns as the Goodyear, Goodrich, Federal, U. S. Rubber, etc. Their demands amount to as much as twenty million pounds a year.

Carbon black is used not only in pneumatic, but in solid tires for trucks as well.

When carbon black is used, the tire will not heat nearly as quick as with the old process where oxide of zinc was used, also the tire will average about twenty per cent. more mileage. The Goodrich Tire Company alone used about 7,000,000 pounds of carbon black in 1918

One Ford automobile tire, 30 x 3½, requires 1¾ lb. of carbon black. The Akron tire manufacturers are making approximately 25,000 tires of this particular size daily.

Carbon Black for Export—As the production of natural gas is decidedly limited in foreign countries and the use of carbon black is just as great as in this country, there should be a wonderful foreign market for the commodity. It is true we now export large quantities, but it is used mainly for the manufacture of printers' ink.

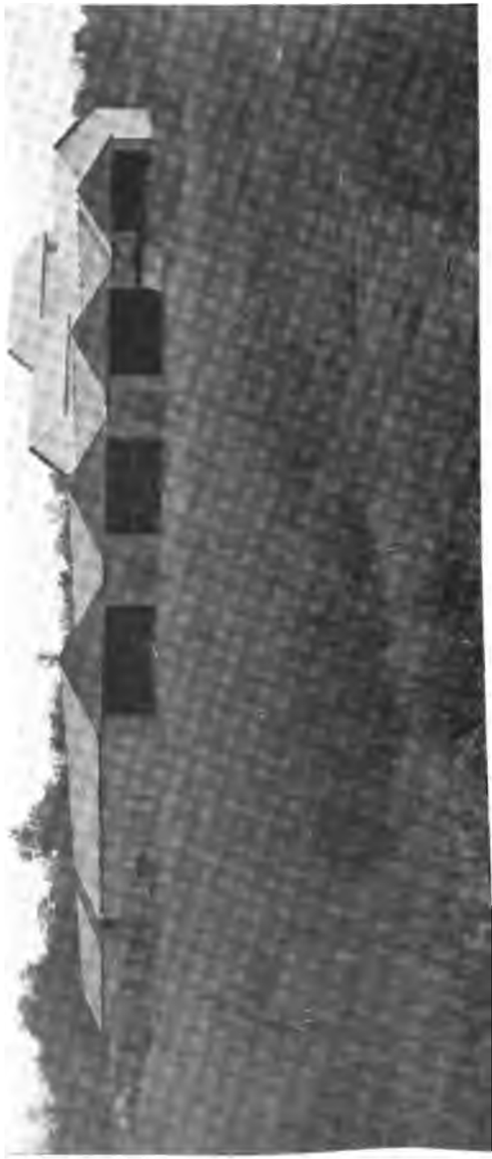


Fig. 219—CARBON BLACK PLANT UNDER CONSTRUCTION

One large tire manufacturer in England is just starting to use carbon black in the manufacture of tires. It is claimed that their output of automobile tires equals about fifty per cent. of all the tires made in this country.

Price of Carbon Black—The price varies according to the grade The common grade is now quoted at eight cents per pound, the high grade, such as Peerless or Intenso, sells for thirty cents per pound, f. o. b. factory.

Prices fluctuate more or less the same as gasoline.

The consumption of Peerless or Intenso grades is very small and while these grades command a high price, more gas and more efficient machinery is required to produce them.

Construction of Plant—It has been the custom of carbon black manufacturers to construct their plants under the supervision of their plant superintendents or practical men who in most cases work from plans and drawings.

The superintendents as a rule are men who have been in the business all their lives and know it very thoroughly.

The following table will give an idea of the number of holes to be punched and drilled in the construction of plant.

TABLE No. 105—Holes to be Drilled and Punched in a 100-Building Carbon Plant.

21000	Pieces 1 in. Pipe 42 in. long -ten $\frac{11}{32}$ in. holes in each pipe drilled.
1	$\frac{19}{32}$ x $3/8$ in., drilled and tapped in bottom of same pipe.
2600	Pieces 1 in. Pipe, 8—$\frac{19}{32}$, tapped left hand.
5600	Pieces 1 in. Pipe, 3—$3/8$, holes drilled, not tapped.
80000	$\frac{19}{32}$ holes drilled and countersunk in 7 in. channel.
80000	$1/2$ in. Punched in 5 in. channel.
10000	$1/2$ in. Punched miscellaneous channels.
33000	$\frac{3}{16}$ in. Drilled in malleable scraper brackets.
33000	$\frac{3}{16}$ in. Punched in scraper weight.
250000	Punched $\frac{5}{16}$ in. holes in angle and flat iron.
130000	Miscellaneous holes to be punched and drilled.

Possibilities of Profit—During the war the price of carbon black was as high as 23 to 24 cents a pound, but at this writing, September, 1919, it is down to 8 cents a pound

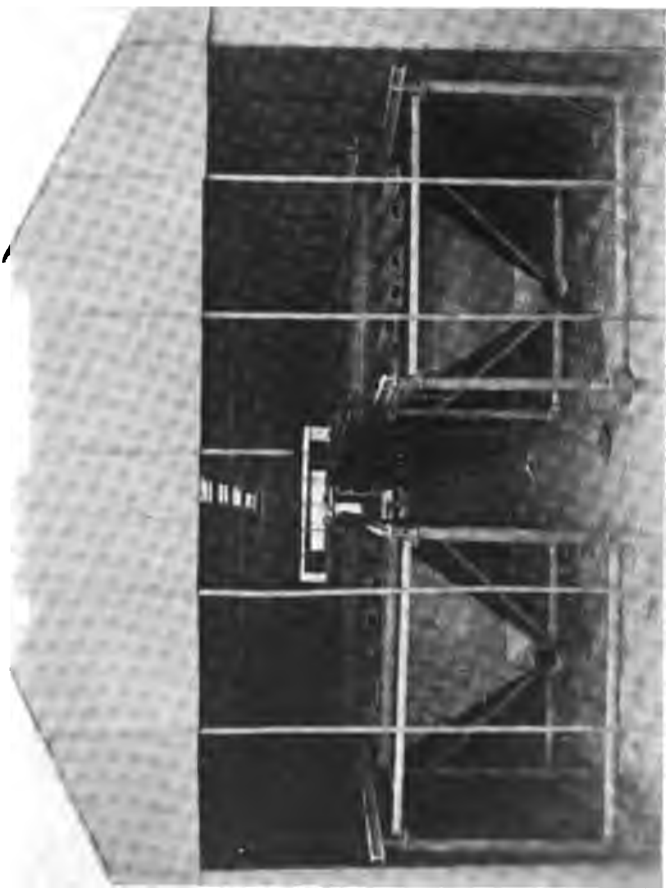


Fig. 220—BURNING BUILDING UNDER CONSTRUCTION. IN THIS PLANT AIR-COOLED SCRAPERS ARE USED INSTEAD OF CHANNEL IRON SCRAPERS

for the common grade. The possibilities of profit are entirely dependent on two things, the price of carbon black and the price of natural gas. It stands to reason if the 0.60 gravity gas sells for 7 or 8 cents per 1000 cu. ft., and carbon sells for 8 cents per pound, there would be no profit in the business. It costs from two to three cents a pound to make it, above the cost of the gas. With gas at two or three cents per thousand and the carbon black selling at 8 cents, there should be a good profit in the business.

Before the war it cost about $60,000 to erect a 30-building plant complete. On account of the large increase in cost of steel and other building materials since then, the cost of a plant of the size mentioned would at least estimate be doubled.

SUBSTITUTES FOR CARBON BLACK

In reply to an inquiry addressed to the Department of Commerce, Bureau of Standards, in regard to what substitutes could be used for carbon black, the following reply was received:—

"1.—Replying to your letter of September 23rd, in which you ask about a substitute for carbon black.

2.—It is hard to see how any black pigment can be made that can even equal the various forms of carbon in cheapness, permanence and other desirable properties. As far as we know, the only cheap black pigment that has been proposed as a substitute for carbon black is a ferrous-ferric oxide which is made from certain waste materials. We do not see how it can be made as cheaply as carbon black. It would also be affected by chemical reagents more easily than carbon."

There have been several patents granted in recent years covering different methods for the manufacture of carbon black from the one so commonly used. These patents are as follows:—

No. 1066894—Method of producing carbon or lamp black. Patent granted to G. Fernekes, July 8, 1913.

Fig. 221—EMPLOYEES' HOMES AT A CARBON BLACK PLANT IN THE MONROE, LA., FIELD

No. 1036363—Apparatus for producing carbon black, granted to J. H. Shnee, August 12, 1912.

No. 877596—Apparatus for producing carbon black, granted in 1908.

No. 866883—Apparatus for producing carbon black, granted to Purtle and Rowland, 1907

The last two patent papers are entirely out of print but the patent office can furnish a reproduction of each in about four weeks time.

Fig. 222

PART NINETEEN

HELIUM IN NATURAL GAS*

BY COLONEL G. A. BURRELL †

The army and navy are intensely interested at the present time in the use of helium instead of hydrogen in "heavier than air" aircraft, *i. e.*, dirigibles, kite balloons, etc. During the war the matter was held secret, but with the cessation of hostilities the government has made public announcement of its work along this line, hence the writer feels at liberty to acquaint the gas industry with the new product obtained from natural gas. In the first place, to stimulate interest in the securing of new supplies, and, second, to show how a substance, long a laboratory curiosity, finally became an exceedingly useful product. The achievement in securing it from natural gas is another one of the many contributions of the oil and gas industry to the cause of the United States and its allies during the war. The writer initiated the project in his work with the Bureau of Mines during the war.

Discovery of Helium—In the year 1869, Lockyear observed in the spectrum of the solar chromosphere a line in the yellow nearly coincident with the double line of sodium, which he denoted as D_3, the wave length of which is 5,875. No terrestrial substance was known containing a corresponding line in its spectrum, and Lockyear and Frankland supposed that this line was due to the presence in the sun of an element which had not been discovered in terrestrial matter, and they, therefore, proposed for it the name "helium." In 1889, Hillebrand, of the United States geological survey, examined the action of dilute sulphuric acid on the mineral

†Consulting chemical engineer, Pittsburgh, formerly in charge of gas investigations, Bureau of Mines. In charge of research for the army and navy during the war.

*Courtesy of the *Gas Record*.

uranite, which consists essentially of a uranite of uranyl and lead containing rare earths, and obtained a gas which he found to have the usual properties of nitrogen and proved that this gas was actually present. After he discovered argon in the atmosphere, Sir William Ramsey, of England, examined gas from the mineral cleveite, which is a variety of uranite, thinking it might contain argon. The result of his investigation showed that the gas from the mineral contained very little nitrogen; the spectrum showed that a small quantity of argon was present, but in addition other bright lines due to helium were noticed which did not occur in the argon spectrum. The most prominent of these was a line in the yellow which appeared to correspond with the line D_3 in the chromospheric spectrum, and this conclusion was confirmed by the exact measurements of Crookes.

Further investigation then showed that helium also may be obtained by heating a considerable number of minerals, although in most cases the quantity obtained is small Most of the minerals which yield the gas contain uranium, and the few in which uranium is not present contain yttrium or thorium. The three minerals which yield helium in the largest quantity are cleveite, the analogous broggerite and the uranium first examined by Hillebrand.

In order to prepare helium, one of the above minerals is powdered and heated in an evacuated tube, the gas evolved being collected over mercury. Any admixed gases, such as hydrogen, oxygen, carbonic acid, hydrocarbons, etc., may be removed in the usual manner, and nitrogen by passing frequently over strongly heated magnesium.

The atmosphere contains a trace of helium, so small, however, as to make any practical process of extraction prohibitive.

Properties of Helium—Helium is remarkable for its inert behavior, and all attempts to cause it to enter into chemical combination have hitherto been without success. The

density of helium is 1.98 (hydrogen = 1). The density of hydrogen compared to air = .06949. The chemical inactivity, the fact that it will not burn, and its lightness, make helium ideal for use in balloons. Some have made the mistake of confusing density with buoyancy or lifting force, and argued that helium being twice as heavy as hydrogen, should have only one-half the lifting power of hydrogen. This is not so. The writer had to meet this argument many times in proposing helium for balloon use. The buoyancy of a gas is measured in terms of an equal amount of air it displaces. Therefore helium really has about 88 per cent. of the lifting power of hydrogen. The atomic weight of helium is 3.96 (O = 15.88). It is the least soluble of all known gases, 100 cc. of water dissolving only 0.7 cc. of the gas. It has also hitherto resisted all attempts to liquefy it. Its normal boiling point is —269 deg. C., about 4 degrees above the absolute zero.

Helium in Natural Gas—In 1907, H. P. Cady and D. F. McFarland discovered helium in some of the natural gases of Kansas, in amounts ranging from a trace up to 1.84 per cent. Other investigators on the continent have discovered traces in natural gas, notably Ozako, in working on the natural gases of Austria-Hungary. The helium-containing natural gases of Kansas, however, have decreased in volume to such an extent that they cannot be used as a source of supply of helium for balloon purposes. No source of adequate supply is known in Europe.

Practical Use of Helium—Up the year of 1917, helium remained only a laboratory curiosity. No practical use had been discovered for it. It had been proposed for use in balloons as a substitute for hydrogen but nobody knew of a satisfactory supply. The writer, when with the Bureau of Mines, before the war broke out, had examined many samples of natural gas. Most important of all he had examined natural gas from Texas and particularly the supply from the

Petrolia fields, notably that of the Lone Star Gas Co., Fort Worth, Texas. He knew that this gas contained about 35 per cent. of nitrogen and appreciated that the helium content frequently followed the nitrogen content, *i. e.*, where the nitrogen content was high, the helium was apt to be high also. Therefore he obtained some of the Fort Worth natural gas from Messrs. Denning and Gage, president and vice president of the Lone Star Natural Gas Co., and forwarded it for analysis to Prof. H. P. Cady, then professor of chemistry at the University of Kansas. Prof. Cady reported that the gas contained a considerable amount of helium.

The writer then asked his colleague in the Bureau of Mines, Dr. F. G. Cottrell, if he cared to recommend any particular method for extracting the helium. Cottrell advised that the F. E. Norton process be tried. Norton was communicated with and stated he felt that his liquefication scheme, still somewhat in the experimental stage, could be used.

The writer by this time had gathered some data on the desirability of the use of helium in balloons, displacing hydrogen. He learned that many kite balloons, used for directing artillery fire and getting other information, were shot down and burned up through incendiary bullets setting the hydrogen on fire. In fact this seemed to be their vulnerable point.

Mr. Manning, director of the bureau of mines, and the writer's chief in the work, took a great deal of interest in the new project. He sent a letter containing the data on the use of helium, as extracted from the Petrolia gas, through Secretary Lane, to the war and navy departments, asking for an appropriation to start the extraction work. Those departments responded with an air allotment of $100,000.

By this time the British admiralty had heard of the work and sent two of its ablest representatives to America to investigate the proposition. These officers became very enthusiastic. They stated that the gas was invaluable and

pushed the work to the utmost. Through their interest the army and navy department increased the appropriation, and started, under the supervision of the Bureau of Mines, and army and navy departments, the building of three plants, by the Linde, Claude and Norton processes.

The process is essentially one of liquefication. All of the constituents in natural gas are liquefied except the helium, and then separated from the latter. This is by no means as easy as it sounds. All of the companies had to do considerable experimenting before anything like successful results were obtained.

When the work had progressed to the point where large scale plants were under construction, it passed out of the hands of the writer, and was directed by Dr. F. G. Cottrell, of the Bureau of Mines, and G. O. Carter, of the Navy Department.

When the armistice was signed, about 45,000 cubic feet of helium had been extracted and was waiting shipment overseas. Several million dollars had been invested in plant equipment in Texas. A valuable and hard-working assistant in the work was P. M. Biddison. The Ohio Fuel Supply Co. loaned his services to the government, at the request of the writer. Mr. Biddison's knowledge of natural gas engineering and of the Petrolia supply and Lone Star system, was invaluable. Mr. Gage, vice-president of the Lone Star Co., did everything in his power to expedite the work. The same can be said of L. B. Denning, the president of the company. Mr Manning and Dr. Cottrell, of the Bureau of Mines, early saw the possibilities in the scheme and worked unrelentingly to put it through. G. O. Carter pushed the Linde plant through as the first completed plant. F. E. Norton put all of his time into his process for the extraction work. Many men gave up their time and energy to see it through.

The work is to be continued and further supplies of helium are sought. Balloons, dirigibles, etc., are in danger from fire in peace time.

It can be added that use of helium by the United States could not be duplicated by Germany. She has no known source of helium supply. It also is true that if German Zeppelins had been filled with helium instead of hydrogen, England would have had a hard time dealing with them. England acknowledges this. Balloons filled with helium will be difficult to destroy. Being made of compartments, one of the latter after another will have to be pierced before the bag loses its buoyancy, and one compartment will not catch fire and destroy the whole bag as in the case of hydrogen.

Natural gas to be valuable as a source of supply of helium should contain at least 50 per cent. of the gas. It is probable that even this quantity will offer great difficulty in the extraction work, although with experience in the process and cheaper methods, which will come with practice, even smaller quantities may be valuable. The largest quantity ever discovered in natural gas was something over 2 per cent.

Fig. 223—GAS WELL ON THE MEXICAN BORDER
Master gate is installed below the surface and a heavy plank box built around it. Dirt is banked against the box to a height of about six feet. This was a precautionary measure as it was known that some of the Mexican Bandits operating in that vicinity were equipped with three pound cannon.

PART TWENTY

NOTES ON CASINGHEAD GASOLINE

Fig. 224—MAKING A PHYSICAL TEST FOR GASOLINE CONTENT OF CASINGHEAD GAS

Casinghead Gas and Gasoline—As this subject has been carefully covered in the "Hand Book of Casinghead Gas," published by this company, only such information that is new will be included in this book. No attempt is made to present a connected story on the subject as the new material included in it relates to various branches of the work.

AN ABSORPTION METHOD FOR THE DETERMINATION OF GASOLINE IN NATURAL GAS

By W. P. Dykema and R. O. Neal

This paper deals with a method of testing natural gas for gasoline content, which has been found satisfactory in testing rich or "lean" gases from wells or the residual gas from compression or absorption plants, at practically all pressures.

The natural-gas gasoline industry has had a rapid growth since 1913, when the first absorption-gasoline plant was erected for the extraction of gasoline from natural gas, and is now not only being applied successfully to dry gas but also

to wet or casinghead gas, stock and make tank gases, still vapors, and residual gas from compression gasoline plants.

In 1917 there were 102 plants, using the absorption process, in the United States, which had an annual production

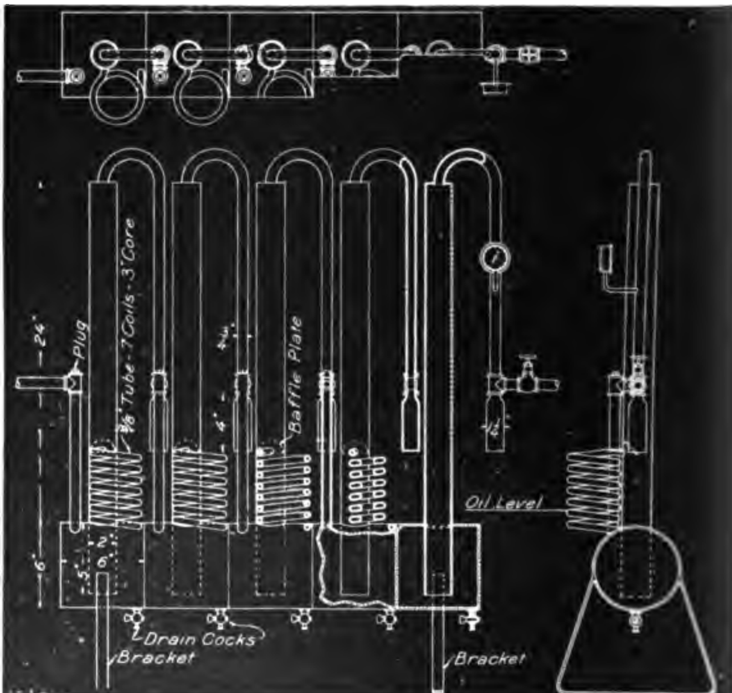


Fig. 225—THE DYKEMA ABSORBER USED FOR DETERMINING THE GASOLINE CONTENT OF "LEAN" NATURAL GAS OR CASINGHEAD GAS

of 49,017,549 gallons, valued at $9,592,026.00*. This process has been one of the most important developments in the natural gas industry, for it has not only saved and utilized what was formerly wasted, but has helped producers to meet the ever increasing demand for motor fuels.

*Northrop, J. D., U. S. Geological Survey Report.

Fig. 226—VIEW OF BURKBURNETT OIL FIELD SHOWING A LARGE CASINGHEAD GASOLINE PLANT IN THE FOREGROUND

Methods for determining the gasoline content of gas have been considered in several Bureau of Mines papers.* Tests of small samples of gas by specific gravity determination, change in volume of gas in contact with an absorption

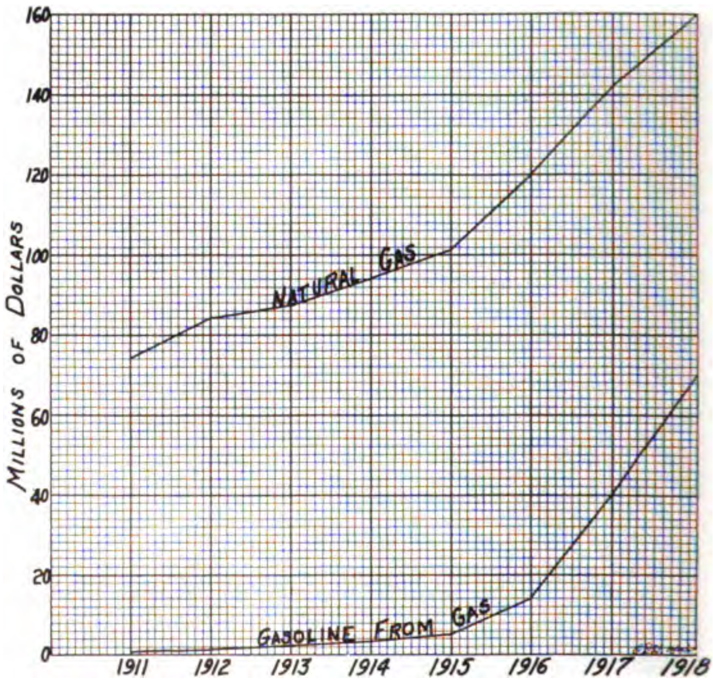


Fig. 227—CHART SHOWING THE COMPARATIVE VALUE OF SALES OF NATURAL GAS AND GASOLINE FROM 1911 TO 1918

Note—The sales of gasoline for 1918 about equal the sales of natural gas in 1911. No doubt in a few years they will more than equal them.

medium, or increase in volume of absorption menstruum, merely indicate the quantity of gasoline in the gas and often

*Bulletin 88, Condensation of gasoline from natural gas. Bulletin 120, Extraction of gasoline from natural gas by absorption process. Bulletin 151, Recovery of gasoline from natural gas by compression and refrigeration. Tech. Paper 87. Methods of testing natural gas for gasoline content.

lead to ambiguous results. The only accurate method of determining the gasoline content of gases that contain less than a gallon of gasoline per thousand cubic feet is to allow a given quantity of the gas to come in contact with some absorption medium and to separate the absorbed gasoline from the oil by distillation. The method outlined in this paper is effected by using an absorption apparatus that differs somewhat in design from any previously described, although it embraces the same principle of operation—that of the Friedrich's wash bottle. This absorber, designed by the senior writer, has the advantage of being a rigid unit, with a large capacity for oil and consequently a larger gas capacity. By using larger volumes, more representative determinations can be made and the opportunities for error are materially decreased. This type of tester is also adapted to plant efficiency, control being used in parallel with the plant in 24-hour runs on both incoming and residual gases.

Before the plant for recovering gasoline from natural gas is constructed, the quantity and quality of the gas to be used should be thoroughly examined. Often one sees plants that, because of the lack of adequate testing of the gas, were erected only to be abandoned as complete failures after a short period of operation. At present, there is no excuse for such conditions existing as a result of inadequate preliminary examination of the gas to be treated. Too much emphasis can not be placed upon the importance of testing gas before the construction of a plant is planned.

The apparatus shown in Fig. 225 consists of a piece of 6-inch casing with five separate compartments, each of which is connected with a ¾-inch gas inlet and also with a 2-inch gas discharge pipe or separate chamber which extends to a point near the bottom of the casing. From the casing runs a ⅜-inch pipe coiled around a 3-inch core with 7 turns, through which the gas being treated bubbles and in which most of the absorption takes place. Some small modifications and

additions, optional in the design, are not shown in the sketch, the use of needle valves at each extremity of the apparatus, in order that gas may not be introduced too rapidly (especially when making an examination of a high pressure gas) or may be throttled to any desired pressure so as not to carry oil over from one compartment to the next, also the use of a needle valve on discharge end to enable one to regulate more easily the rate of flow through the meter, especially in tests at low pressure, that is, when the gas flows through the absorber very slowly. It is advantageous to use gate valves instead of drain cocks for drawing off treated absorption oil from the oil chambers, as such valves facilitate rapid work and eliminate the possibility of volatilization losses when oil is allowed to spray through a stop-cock under pressure into the container for collecting treated oil. Also, time can be saved by using small bull-plugged nipples on the oil charging pipes, in place of standard plugs, as they can be more easily removed and more rigidly connected to prevent leaks.

To make the test with this absorber, 2700 cc. of mineral seal oil, or enough to bring the level of the oil about 2 inches above the top of the 6-inch casing and well above the coil inlet, is accurately measured and introduced into each compartment. The most important requisite for absorption media is high initial boiling-point, in order that in the subsequent distillation, a quantative separation can be effected. The oil used in the tests described in this paper had the following physical properties:

Gravity	36.0 deg. Be.
Initial boiling point	450 deg. fahr.
Viscosity at 70 deg. fahr.	51 Saybolt
Flash point (Pensky-Martens closed test)	271 deg. fahr.
Fire test (Pensky-Martens open test)	307 deg. fahr.

In most tests only the first three absorbers are used but it may be expedient to fill the fourth compartment when ex-

amining rich gases at low pressures or when running a large volume of dry gas in paralleling a 12-hour, or day's operation of an absorption plant to determine the extraction efficiency. The fifth division is not intended to be used as a container for oil, but to serve as a separator or oil trap in case any oil is carried over from the preceding compartment. A meter capable of measuring from 1 to 1,000 cubic feet of gas accurately is connected to the discharge of the absorber.

The gas to be tested is allowed to slowly enter the apparatus with the discharge valve closed, and when pressure equilibrium with the gas to be examined is obtained, or when the desired pressure is attained, the discharge valve is opened enough to permit the desired rate of flow through the meter.

The gas entering the absorber bubbles up through the oil, the latter absorbing the gasoline. The function of the pipe coil is to provide a long and intimate contact between the oil and the gas as the gas passes through the absorber.

After the desired quantity of gas has passed through the absorber the supply is shut off and the pressure is released, through the needle discharge valve, allowing all the gas to flow through the meter. After the pressure has decreased to atmospheric pressure, all of the oil is withdrawn through gate valves at the bottom of the casing and the oil from each compartment is accurately measured, 1000 cc. of treated oil from each compartment being kept for distillation.

Distillation of Saturated Oil—Of the treated oil 400 cc. is introduced into a 500 cc. Engler distilling flask connected to a condenser made of ½-inch brass tubing and surrounded by cold (iced) water contained in a metal box.*

The flask is heated by direct fire, slowly at first, and the gasoline driven out of the oil is collected in a 25 or 50 cc. graduated cylinder, which should be surrounded by ice to eliminate the evaporation losses. The flask is heated until the vapor reaches a temperature of 350 deg. fahr., which

*Am. Soc. Test. Mat. Year Book, 1915, pp. 568-569, and 1916, Vol. 16, pp. 518-521.

usually requires 20 minutes. If the oil has a very high saturation, it is allowed to cool 20 to 30 deg. and again raised to 350 deg. This procedure is followed until practically no more gasoline is driven over and collected from the condenser. Great care must be taken in reaching 350 deg., the ring of mineral seal-oil condensed in the neck of the flask must never be allowed to reach the delivery tube.

The extraction of gasoline by the oil will depend upon the rate of flow, gasoline content of the gas, volume of gas treated, pressure and the temperature of the absorbing oil. Optimum conditions, as regards volumes of gas and rate of flow with gases at different pressures and gasoline content, are given below.

TABLE No. 106

Controlling Factors in Operation of Test Absorber:

Maximum rates of flow of gas. Cu. ft. per hour	Pressure. Lb. per sq. inch
400	300
200	150
100	75
50	40
20	Atmospheric

TABLE No. 107—MAXIMUM GAS CAPACITY

Cu. ft. of Gas	Gasoline—gal. per 1000 cubic feet.
800	.125
400	.250
200	.50
150	.75
100	1.00
66	1.50
50	2.00
35	3.00
25	4.00

The following data were obtained from a representative test made upon the intake gas at a compression plant in the Mid-Continent field.

Test No. 2 c.

INTAKE GAS.

Temperature of oil	94 deg. fahr.
Pressure	204 lb.
Rate of flow	133 cu. ft. per hr.
Volume	302 cu. ft.

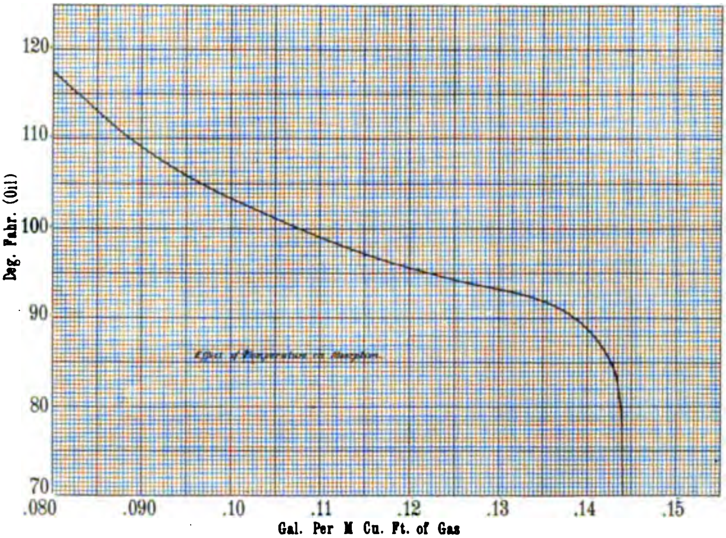


Fig. 223

TABLE No. 108

	Compartments		
	1st	2nd	3rd
Charge	2600 cc.	2600 cc.	2600
Recovered	2700	2600	2630
Gravity of oil	37.0° Be	36.4	36.0
Distilled	400 cc.	400	400
Initial C. B.	170 deg. fahr.	185	308
Gasoline	19.5	9.5	3.5
Total each	131.5 cc.	63.2	23
	217.7	cc. 78° Be.	gravity)
Proportion extracted in each compartment	60.5 per cent	29.0 per cent	10.5 per cent
Gasoline content	0.190 gal.	per 1000	cu. ft.

The gasoline content is calculated by using the following formula:

$$Q = \frac{1000}{G} \times \frac{C}{3785}$$

where Q is the gasoline content in gallons per 1000 cubic feet of gas, G is the volume (cubic feet) of gas treated, and C is the total number of cubic centimeters of gasoline obtained from the treated absorption medium, based on the quantity of oil taken out of the absorber.

The temperature, above certain limits, of the absorbing oil has probably more effect on the efficiency of extraction than any other factor. In a series of tests of dry gas with all conditions constant, except the variable factor of temperature, a difference of 42 per cent. in the volumetric recovery of gasoline for a gradient of 30 deg. fahr. was obtained, as is shown by the curve in Fig. 228. These changes took place between 90 deg. fahr. and 120 deg. fahr. and are undoubtedly due to the rapid increase in the partial vapor pressure of the gasoline fractions in the gas as their boiling points are reached. The gas at 70 deg. fahr. contained .144 gallons per thousand cubic feet of gas and this figure is taken as 100 per cent. as shown on the curve. Probably no two gases will show the same results with the same variation in temperature, inasmuch as the characteristics of the gasoline hydrocarbons are distinctly dissimilar. The data from which this curve was plotted were obtained from a series of tests using a constant quantity of oil (2700 cc. of oil in each of the first three compartments), a pressure of 130 pounds per square inch and a total volume of gas of 200 cubic feet which passed through the apparatus at the rate of 2 cubic feet per minute. The data obtained in this test are not a criterion by which to judge other gases, as cognizance must be taken of the fact that although gases may have the same gasoline content,

still the characteristics of the various hydrocarbons contained, will be altogether different and consequently will require different operation methods and give varying results under test such as the above.

The test absorber and the method described in this paper is recommended in preference to the use of those scrubbers mentioned in other publications because it gives more significant results when evaluating a gas with the idea of determining the feasibility of installing an absorption gasoline plant, or of ascertaining the efficiency of extraction at absorption or compression gasoline plants.

TEST OF CASINGHEAD GAS WITH THE DYKEMA ABSORPTION TESTER.

Pressure	15 lb.
Volume	52.7 cu. ft.
Temperature of oil	97 deg. fahr.

	Compartments.			
	1st	2nd	3rd	4th
Charge	3000 cc.	3000 cc.	3000 cc.	3000 cc.
Recovered	3100	3050	3000	3000
Distilled	400	400	400	400
Gasoline	4.5	4	3.5	2.00
Total gasoline each	34.87*	30.5*	26.25	15.00
Grand Total	106.62 cc.			
Proportion extracted in each compartment	32.70 per cent	28.60 per cent	24.62 per cent	14.07 per cent
Gasoline content	.53 gal. per thousand cubic feet			

Tested by: R. O. NEAL and D. B. DOW.

*Due to high working temperature, saturations in first two compartments became approximately equal. This is unusual under average testing conditions.

Fig. 229 GASOLINE ABSORPTION PLANT CAPABLE OF HANDLING ½ MILLION CU. FT. OF GAS PER DAY

THE NEWTON ABSORPTION TESTER.

The Newton Absorption Tester, shown in Fig. 230, is a very simple field apparatus that the layman can easily operate without the aid of a distillation outfit. It was originally designed by Mr. D. L. Newton, of Fullerton, Calif. The figures given were mainly obtained by practical tests at gasoline plants where the amount of gasoline obtained from the gas absorption process was known. This apparatus will not show the full amount of gasoline in the gas but will show the amount of gasoline that can be obtained at an efficient absorption plant of large capacity.

The apparatus consists of an absorber, 10 feet of ¼-inch hose, a siphon gauge, a relief valve or regulator, and some mineral seal oil of 35 deg. Baume gravity. The entire outfit is carried in a metal case 24 in. by 6 in. by 6 in (with top off) and a well can be tested within forty-five minutes.

Instructions for Use are as Follows

Make connection with the gas to be tested, as shown in Fig. 231.

Allow the gas to run through the hose a few minutes.

Place absorber in a vertical position and pour mineral seal oil into the absorber until you have 125 cc., which is indicated on the glass on the side of the absorber.

Connect hose with absorber.

Eight inches of water pressure should be carried on the gas. The relief valve will assist in keeping this pressure constant.

Take the time when the gas is first turned into the absorber and allow it to run through it for thirty minutes.

Note the reading of the mineral seal oil level on the glass and deduct from original level reading.

Multiply the difference or increase in cc. by 1 ⅓ and the result will be pints per thousand cubic feet of gas.

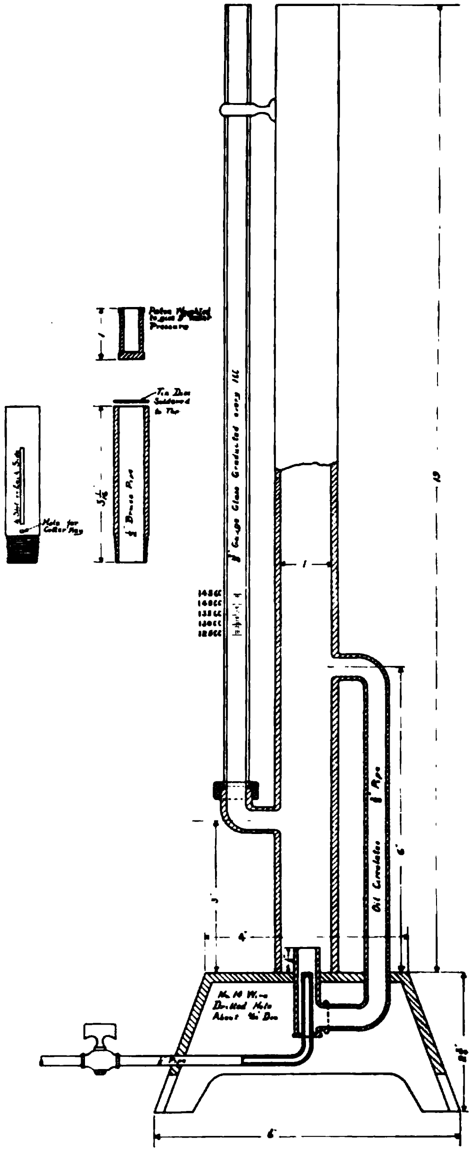


Fig. 230—SECTIONAL VIEW OF THE NEWTON ABSORPTION TESTER

The orifice on the end of the short nipple screwed in the center of the lower end of the absorber will pass a certain amount of gas per hour at an eight-inch water pressure. This orifice should be kept in perfect condition.

The best results have been obtained by keeping the temperature of the gas about 80 deg. fahr. The results will not change very much if the temperature ranges between 70 and 90 deg. fahr. The temperature can be controlled by running the hose through either hot or cold water.

The apparatus has one factor of error and that is the effects of water vapor. This can be checked by making a test, then distilling the sample of mineral seal oil. Distill sample and subtract water from the increase.

In over a hundred tests made with this instrument it was not found necessary to give water vapor any attention.

There are several of these outfits in use on the coast at this writing and their owners are meeting with good success with them.

In operating at 80 deg. fahr. and being violently agitated, the mineral seal has a tendency to throw off the higher series of hydrocarbons, such as butane, etc., which might otherwise upset the reading and also as the machine was calibrated from the plant production these series were originally taken care of.

AUTOS AND TRUCKS.

State registration of motor cars (including trucks) on December 31, indicated nearly 7½ million motor-driven vehicles in use. New York State led in the number with 572,000, followed by Ohio with 512,000; while California, with 490,000, ranks third. The rank of these States would be changed somewhat if we considered the ratio of cars to population. Of these, California ranks first with one motor vehicle for every 6.2, while Nebraska and South Dakota are

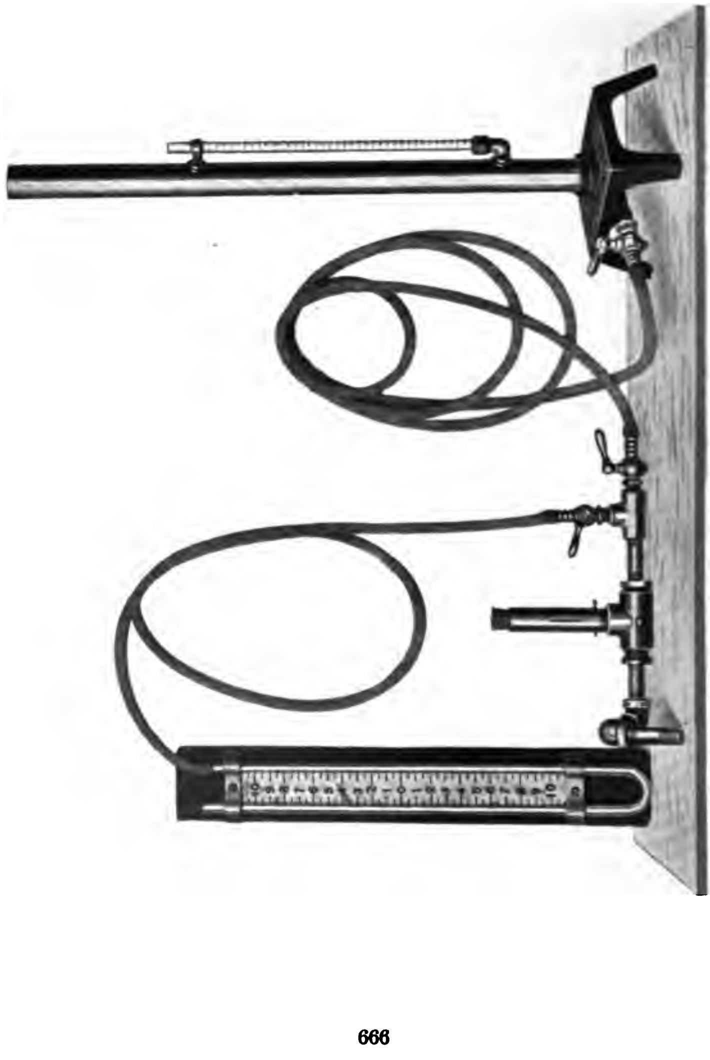


Fig. 231—THE NEWTON ABSORPTION TESTER

next with a figure of 6.8. If we consider the census figures of 4.4 persons per family, we find that in California there is one motor vehicle for every 1.4 families, while even Mississippi, which ranks forty-eighth in point of cars per capita, boasts of one motor vehicle for every 9.6 families.

And still manufacturers are behind in their orders; and customers for some of the same popular types of cars are forced to wait five and six months for deliveries.

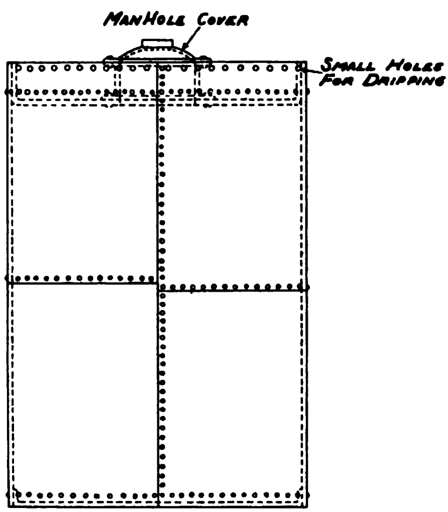


Fig. 232—SMALL GASOLINE TANK EQUIPPED WITH SUNKEN TOP FOR HOLDING WATER

PART TWENTY-ONE

PETROLEUM NOTES

PRODUCTION AND CONSUMPTION — CHEMICAL CONSTITUENTS—DEVELOPMENTS IN PETROLEUM INDUSTRY IN TEXAS — DERRICKS IN COLOMBIA, S. A.—CAPACITIES OF PIPE-LINE CHART — OIL AND GAS SEPARATORS.

The following summary of the quantity of crude petroleum produced, consumed, and held in storage in the United States for the fields east of Calfornia is based on reports filed with the United States Geological Survey, and that for California in 1919 is the average of figures collected by the Standard Oil Co., and the Independent Producers' Agency. Data for 1919 is subject to revision.

Monthly Fluctuations in Average Daily Rate of Production and Consumption, and in Stocks of Domestic Crude Petroleum in 1918 and 1919.

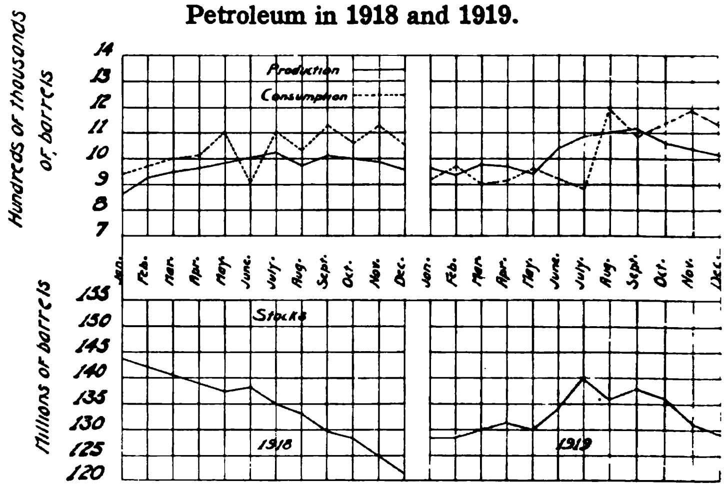


Fig. 233

NOTE: The curves for 1918, based on final figures, and those for 1919, based on preliminary figures, are not directly comparable because of differences in the methods of collecting monthly and annual statistics.

Production—Figures of monthly production for the states east of Calfornia show the quantity of oil received from producers by pipe-line and other marketing companies, and by refineries that receive petroleum directly from the wells. Data concerning oil consumed on the leases and producers' stocks in those states could not be obtained in time for use in the monthly reports. The production of Calfornia which is in part estimated, includes all petroleum brought to the surface by producers.

The production of petroleum in the United States in December, 1919, thus stated, amounted to approximately 32,508,000 barrels. The average daily rate of production was 1,048,645 barrels, which was less by 21,821 barrels than in the preceding month. A decline in production was registered in all the fields excepting North Louisiana, the Appalachian, and the Lima-Indiana.:

TABLE No. 109

Production of Petroleum in the United States.

Barrels of 42 Gallons.

Field	November 1919 Thous.	December 1919 Thous.	Final figures 1918	Preliminary estimates 1919
Apalachian	2,064	2,230	25,401,466	29,232,000
Lima-Indiana	247	259	3,220,722	3,444,000
Illinois	1,033	926	13,365,974	12,436,000
Mid-Continent:				
Oklahoma-Kansas	10,408	10,266	148,798,087	115,897,000
Central and Northern Texas	6,107	5,989	17,280,612	67,419,000
North Louisiana	1,249	1,634	13,304,399	13,575,000
Gulf Coast	1,715	1,758	24,207,620	20,568,000
Rocky Mountain	1,137	1,120	12,808,896	13,584,000
California	8,154	8,326	97,531,997	101,564,000
	32,114	32,508	355,927,716	377,719,000

CHEMICAL CONSTITUENTS OF PETROLEUM

Petroleum is composed of carbon and hydrogen in chemical combination known as hydrocarbons. In conjunction with C and H there are frequently oxygen, nitrogen, and sulphur in much smaller amounts.

In crude oil the amount of C varies from 80 to 89 per cent, the H from 10 to 15 per cent, O from 0.0 to 5 per cent, N from 0.0 to 1.8 per cent and S from .01 to 5 per cent.

Typical ultimate analyses of petroleum products are as follows:

TABLE No. 110

All values given in per cent.

	C	H	S	N	O
Pennsylvania Crude	86.06	13.88	0.06	0.00	0.00
Texas Crude	85.05	12.30	1.75	0.70	0.00
California Crude	84.00	12.70	0.75	1.70	1.20
Mexican Crude	83.70	10.20	4.15	0.00	0.00
Oklahoma Crude	85.70	13.11	0.40	1.30	0.00
Kansas Crude (Towanda)	84.15	13.00	1.90	0.45	0.00
Kansas Residuum	85.51	11.88	0.71	0.32	0.63
Kansas Air Blown Residuum	84.37	10.39	0.42	0.21	4.61
Byerlite Pitch	87.61	9.97	0.55	0.29	1.59
Grahamite	87.20	7.50	2.00	0.20	0.00
Trinidad Asphalt	82.60	10.50	6.50	0.50	0.00
Commercial Gasoline	84.27	15.73	0.00	0.00	0.00
Kerosene	84.74	15.26	0.01	0.00	0.00
Lubricating Oil (Paraffin)	85.13	14.87	0.01	0.00	0.00
Lubricating Oil (Naphthene)	87.49	12.51	0.01	0.00	0.00
Benzol	92.24	7.76	0.00	0.00	0.00

Paraffin (C_nH_{2n+2}) hydrocarbons largely compose the light or more volatile constituents of all petroleum. They are "saturated" hydrocarbons and have a very low ratio of specific gravity to distilling temperature, are not acted on by concentrated sulphuric acid or by fuming sulphuric acid (oleum); are not nitrated by nitric acid and are extremely resistant to all chemical reactions. The chief differences in petroleum are in the heavy constituents, the heavy hydrocarbons of the paraffin series being found chiefly in Pennsylvania and some mid-continent oils.

Naphthenes (C_nH_{2n}) ring or cyclic compounds, are less common hydrocarbons in lighter portions of petroleum, but

commonly found as heavy hydrocarbons of petroleum. They have a higher ratio of specific gravity to distilling temperature than the paraffin compounds, are resistant to the action of sulphuric acid, and some types may be distinguished by the "formolit" reaction. Oils containing light naphthenes are found in Russia and Louisiana. All heavy oils contain naphthenes.

Aromatic or benzene hydrocarbons (C_nH_{2n-6}) exist to some extent in certain California petroleums and have a very high ratio of specific gravity to distilling temperature. Gasoline made from the California petroleum is heavier than light gasoline with the same end point made from mid-continent petroleum. The aromatic compounds are acted upon by nitric acid forming nitro-products. They are formed from paraffin and naphthene hydrocarbons by pyrogenic decomposition at temperatures above 1000 deg. fahr. The production of aromatic compounds from petroleum has not been commercially satisfactory on account of incomplete conversion and difficulty of freeing from paraffin hydrocarbons.

Olefines or ethylenes (C_nH_{2n}) are "unsaturated" hydrocarbons, rarely if ever existing naturally in crude oil but commonly resulting from its exposure to high temperatures. These compounds contain less hydrogen and more carbon than paraffin hydrocarbons and are capable of taking in more hydrogen. They are removed from aromatic compounds, paraffin compounds, and napthene compounds by the action of concentrated sulphuric acid in the usual process of refining gasoline. These hydrocarbons give gasoline, to a large extent, its disagreeable odor before refining. Their combination with sulphur gives a more intense odor. Each of these groups of hydrocarbons is supposed to exist in a complete series, represented by the general formula given. The paraffin or methane series of "saturated" hydrocarbons has been fairly well worked out and is given in table No. 12 opposite page 110.

Fig. 234—OIL WELL AT TEPATATE, MEXICO, FLOWING 80,000 BARRELS OF OIL PER DAY. GRAVITY OF OIL 20.4, ASHPALT BASE

There is no natural petroleum composed exclusively of the paraffin series of hydrocarbons, even Pennsylvania and Garber, Okla., crude oils having members of other series. The main body of the light petroleum is made up of paraffin hydrocarbons and the heavy residues are largely made up of naphthenes.

According to Hofer, the following olefines have been isolated from "North American" petroleum:—

TABLE No. 111

Ethylene	C_2H_4	Heptylene	C_7H_{14}	Dodecylene	$C_{12}H_{24}$
Propylene	C_3H_6	Octylene	C_8H_{16}	Decatrilene	$C_{13}H_{26}$
Butylene	C_4H_8	Nonylene	C_9H_{18}	Cetene	$C_{16}H_{32}$
Amylene	C_5H_{10}	Decylene	$C_{10}H_{20}$	Cerotene	$C_{27}H_{54}$
Heyylene	C_6H_{12}	Endecylene	$C_{11}H_{22}$	Melene	$C_{30}H_{60}$

If the residue contains much wax, the crude is known as "paraffin" but if napthenes or similar hydrocarbons predominate, it is an "asphalt" base oil; practically the "asphalt" is determined by the solubility of the solid hydrocarbons in pentane and by the gravity and physical character of the residue.

Among the light hydrocarbons of petroleum, either existing naturally or pyrogenically produced, the relation of the specific gravity to the distilling temperature affords a simple and practical method of estimating the amount of olefin, paraffin and aromatic compounds.

The value of crude oils is not measured by its ultimate analysis or by its "base" so much as by the amount of volatile constituents which it contains.

PRESENT DEVELOPMENTS IN THE PETROLEUM INDUSTRY OF TEXAS

By E. H. SELLARDS.*

From small beginnings of some thirty years ago the petroleum industry of Texas has advanced by successive large discoveries to its present position as the leading mineral

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industry of the state. The advance has been remarkable, particularly in recent years. By way of comparison there is here given the yearly percentage increase for five years previous to 1918 as reported by the United States Geological Survey. The production in barrels of 42 gallons is as follows:

TABLE No. 112

Year	Barrels	Per cent increase over previous year
1913	15,009,478	27
1914	20,068,184	34
1915	24,942,701	24
1916	27,644,605	11
1917	32,413,287	17

The production for 1918 was about 37,826,925 barrels. The estimated production for 1919 is between 90,000,000 and 100,000,000 barrels, or approximately 2½ times the production of 1918. By these remarkably advances, Texas has become one of the leading oil producing states in the United States.

This large production is the more remarkable when contrasted with the slow development of the industry at its inception. Among early unsuccessful attempts to utilize the petroleum of Texas commercially should be mentioned those which center around the oil springs of Naeogdoches County, the gas wells of Washington County, and the shallow oil wells of Bexar County. Small quantities of oil are said to have been taken from the oil springs of Nacogdoches County as early as 1867*. Test wells near the springs, some of which were productive in a small way, were subsequently drilled, and by 1890 at least 20 wells were producing at this locality in addition to many others that had either been unsuccessful or had been abandoned after a limited production. All of these wells were shallow, those of which the depth is recorded being from 70 to 252 feet deep, although some deeper wells have since been drilled in this locality.

An early attempt to utilize gas in Texas was made at Greenvine in Washington County, where two or three wells

*Texas Geological Survey, 2nd Annual Report, 1890, page 272.

were drilled between 1879 and 1883, and about three others in 1888. These wells were shallow, being less than 200 feet in depth. Subsequent deeper drilling has shown the presence of oil in small quantities near this locality. In Bexar County, a well drilled about 1886 for water on the Dulnig property seven miles southeast of San Antonio, obtained a limited amount of oil at about 235 feet and in other wells subsequently drilled near by at about 300 feet†. As a producer of petroleum Texas appears first in statistical tables about 1886, the small production at that time being probably entirely from the Nacogdoches County field.

The first oil field of any considerable commercial importance to be developed in Texas was at Corsicana, in Navarro County. This field, the development of which began about 1895, proved to be extensive and long lived and from 1895 to 1900 afforded almost the whole petroleum production of Texas. According to G. C. Matson, 642 wells had been drilled in this area by the close of 1889, of which 511 were oil wells, 13 gas wells, and 18 dry holes. The production from this field for 1899 was 668,483 barrels*. The year 1900 witnessed the extension of the Corsicana field by new discoveries farther to the east, which led to the development of the Powell field. With the discovery of the Spindletop pool in 1901 there was inaugurated the very active period of exploration which developed the large oil fields of the Gulf coast of Texas.

As early as 1900 shallow oil in small quantities was found in wells drilled for water in Wichita County, near the north boundary of Texas.‡ However, notwithstanding the subsequent discoveries of the large oil pools on the Gulf coast, developments in this north Texas field were relatively unimportant until about 1910, when the discovery of a large producing well was followed by the development of the

†University of Texas Bulletin No. 5, page w., 1901.
*U. S. Geological Survey, Bulletin 661, page 249, 1917.
‡University of Texas, Bulletin 246, page 117, 1912.

Electra and Petrolia fields of Wichita and Clay Counties. Another epoch in the development of the oil resources of north-central Texas dates from 1917, when wells in Stephens County, passing through the formations that had previously yielded oil in this area, entered and obtained oil from the Bend series. The great importance of the Bend as a large producing formation was further demonstrated in 1917 by the discoveries at Ranger. These discoveries gave renewed impetus to the then active explorations which have led to the present very great production in north central Texas.

Producing Areas and Fields in Texas—The principal oil fields of Texas lie in three large areas as follows: north-central Texas, the inner margin of the Coastal Plains, and the Gulf margin of the Coastal Plains. In addition, small quantities of oil have been reported in the Pecos Valley and at some other localities.

Of these several areas the north central Texas fields are now leading both in the quantity and value of production, this section of the state having produced in 1919 more than 70,000,000 barrels of oil. The oil, which in this area is obtained from the Paleozoic formations is of light gravity, and is desirable for refinery purposes.

This central Texas area is limited at the south by the large uplift known as the Central Mineral Region in which the oldest of the oil bearing formations are brought to the surface. To the west the limits of the oil bearing area is unknown, and can be determined probably only by further drilling. To the east the limits are likewise undertimed while to the north the producing area extends into Oklahoma. The counties within this area in which oil and gas have been found in commercial quantities include: Archer, Brown, Callahan, Clay, Coleman, Comanche, Eastland, Erath, Jack, McCulloch, Palo Pinto, Parker, Shackelford, Stephens, Wichita, Wilbarger, and Young. The producing fields of this area include the following: Breckenridge,

Brownwood, Burkburnett, Caddo, Desdemona, Electra, Iowa Park, Moran, Petrolia, Ranger, Strawn, Trickham, and some other smaller fields. Explorations within this area are very active, and both the number and relative importance of fields are rapidly changing.

The formations yielding oil in the north central Texas area include those of the Bend series, together with some of the formations of the overlying Pennsylvania and Permian series. The Bend series includes the Lower Bend shales, the Marble Falls limestone, and the Smithwick shales. The production from the deep wells of Brown, Coleman, Comanche, Eastland, Stephens and Young counties, including Desdemona, Breckenridge, Caddo, Ranger and some smaller fields is from these formations. The Bend is placed by some as Pennsylvanian, and by others as in part Missippian. The Pennsylvanian above the Bend includes the Strawn, Canyon, and Cisco formations, all of which have produced more or less oil. The production at Moran, and at Strawn is from the Strawn formation. The production at Trickham and in the shallow field at Brownwood is from near the base of the Canyon or from near the top of the Strawn. The production in the Petrolia and Electra fields of Clay and Wichita counties from 750 and 1000 feet is probably from the Cisco; while the deeper production in these fields from 1700 and 1900 feet is from the Cisco or from the upper part of the Canyon. The large production at Burkburnett is probably from the Cisco. From the Permian series, Wichita formation, is probably obtained the oil of the shallow sands of the Petrolia and Electra fields. The large gas production obtained near Amarillo is likewise from the Permian.

The formations lying at the surface in north central Texas include, aside from Cretaceous remnants, those of the Upper Pennsylvanian and Permian systems. The Cretaceous formations which are best developed towards

the east side of the area, dip to the east or southeast. The Upper Pennsylvanian and Permian formations, including the Strawn, Canyon, Cisco, and Wichita, on the other hand dip northwest or north-northwest. The prevaling northwest dip of these formations is locally interrupted, producing terraces, and the surface structure is further complicated by the presence of small northwest plunging anticlines.

The principal structural feature controlling production in this area is a large regional fold which originates in the Central Mineral Region and extends slightly east of north. This fold which has been located by well drilling as far probably as Young County, plunges to the north, the plunge, as indicated by the position of the Ellenburger limestone, which underlies the Bend formations, amounting probably to an average of between 40 and 50 feet per mile. Thus from surface exposures in San Saba County approximately 1250 feet above sea level this formation, the Ellenburger, descends to approximately 2500 feet below sea level at the Eastland-Stephens County line, a change in level amounting to about 3750 feet in a distance of between 90 and 100 miles. The Bend series which underlies all north central Texas is affected by this fold which for that reason is known as the Bend Arch.

Inasmuch as large unconformities separate the Ellenburger from the Bend as well as the Bend from the overlying Pennsylvanian and Permian formations, and these in turn from the Cretaceous formations where present, the probability of the presence of structures in the deeper formations not reflected in the surface formations is apparent. On the other hand the extent to which observed surface structures reflect larger structures in the deep formations is a problem of much concern to the industry. The developments to the present time indicate relationship, but probably not complete harmony between surface structures and structures in the Bend formations. On this subject many observations and

a large literature is accumulating, and we shall have to look to the future for the solution of the problem.

In Clay and Wichita counties near the north Texas line, where the production is chiefly from the Cisco formation, the trend of such structures as have been recognized, according to Udden, is west-northwest to east-southeast. From these observations it seems probable that in this area including the Petrolia, Electra, and Burkburnett fields, the regional structure is distinct from that of the remainder of the north central Texas area.

Although variable the formations of the Bend series reach a combined total thickness of about 1250 feet. The depth below the surface at which these formations are reached and production obtained increases in passing to the north from the Central Mineral Region. The depth to these formations likewise increases rapidly in passing either east or west from the axis of the large fold. The southernmost wells obtaining production from the Bend, those of Brown County, obtain oil at a depth of 2400 or 2500 feet, while the northernmost well obtaining oil from this formation in Young County reaches a depth of 4600 feet. Much of the production, which comes apparently from various levels in the Bend formations, is from limestones, true siliceous sands being present to only a limited extent within these formations. In the formations later than the Bend, the Strawn, Canyon, and Cisco, sands are much better developed and the production from these formations, in many instances comes from true sands.

The oil fields of the Gulf Coast include the salt dome pools. Production in this area on a commercial scale began with the discovery of the Spindletop pool in 1901. This coastal belt is still a large producer of heavy oil, the production for 1919 being close to 25,000,000 barrels. To the east this area extends into Louisiana; to the southwest the limitations may be regarded as undetermined altho domes

of the general character of those yielding petroleum are found to within a few miles of the Mexican border. The counties in which large producing domes of this type are known at present include: Brazoria, Hardin, Harris, Jefferson, Liberty, Matagorda, and Orange. The large pools within this area include the following: Batson, Damon Mound, Dayton, Goose Creek, Hull, Humble, Markham, Saratoga, Spindletop, Sour Lake, and West Columbia. Of these pools none have been more remarkable in some respects than the first to be discovered, Spindletop, which is estimated to have produced between 45,000,000 and 50,000,000 barrels of oil from a surface area not exceeding 200 acres.

The formations yielding oil in the salt dome fields are those of the Tertiary system. The Fleming formation, which is Miocene or Miocene and Plicoene is regarded by some as the principal oil reservoir of this area. Structurally the producing fields are flat topped domes, which usually contain, in addition to petroleum more or less salt and sulphur. The theories advanced to account for domes of this type are too involved to permit of discussion in this connection. Of the theories advanced, one is that the domes are formed by the crystalizition of salt, and other minerals from upward migrating waters; another theory associates the domes with volcanic plugs.

The oil fields near the inner margin of the Coastal Plains approximately parallel the Balcones fault zone and are sometimes known as the Balcones area. The oil and gas are obtained from the Upper Cretaceous formations, and the area is limited at the west by the outcropping of these formations. To the southwest showings of oil and gas, more or less definite, are reported in this belt to the Rio Grande. To the north the area may be limited by the termination of the Balcones disturbances, although as to the northern limits definite data apparently are lacking. The Balcones area is therefore a narrow belt through the state approximately

paralleling the zone of the outcropping of the Upper Cretaaceous formations. The counties in which fields of commercial importance are located include the following: Atascosa, Bexar, Limestone, Navarro, and Williamson. In addition small showings of oil have been found in many other counties of this area. The fields of commercial importance, with the date of their discovery, are as follows: Alta Vista, 1915; Corsicana, 1895; Groesbeck, 1915; Mexia, 1912; Mission, 1915; Powell, 1900; Somerset, 1913; Swearingen, 1917; and Thrall, 1915. Although this area includes the first field of commercial importance developed in Texas, Corsicana, the area at the present time is small in production as compared to the areas already described.

The oil of the Balcones area is found in the Eagle Ford, Austin, Taylor, and Navarro formations. From the Eagle Ford, scarcely more than showings of heavy oil have been reported. Commercially productive horizons within this formation are not known within this area altho gas and a limited quantity of heavy oil is said to have been derived from the Blossom sands near the top of this formation in the Caddo fields of Louisiana and eastern Texas. The Austin formation produces heavy oil, 14 to 16 Be., in the Alta Vista and Mission fields of Bexar County. Likewise the Anona chalk member of this formation produces a limited quantity of heavy oil in the Caddo field of Louisiana.

The Taylor and Navarro formations afford the largest production of any of the Upper Cretaceous series. The wells from these formations have been as a rule relatively small producers, but are long lived. An exception to this rule was found in the Thrall field where the production was large and the wells short lived. In this field, however, the conditions are exceptional in that the oil is held in an igneous rock intrusion in the Taylor formation. The principal production at Corsicana is from the Taylor formation. From the Navarro formation or its equivalent is

obtained the principal gas supply together with a limited amount of oil in the Mexia, Groesbeck, Powell, and Caddo (Louisiana) fields. In the Somerset field of Bexar County the production is probably chiefly from the Navarro formation, altho some of the oil of that section may come from the Taylor below the Navarro and some from the overlying Midway. The gravity of the oil from the Corsicana and Thrall fields is from 36 to 40 Be. That from the Somerset field varies from about 30 to 40 Be.

Altho not within the Balcones area a few other localities in the coastal plains merit mention. Among these is the extension of the Caddo field of Lousiana into Texas in Marion and Harrison counties. Another locality of historic interest is that at Nacogdoches already referred to. The small production obtained at this locality, and also a small production at Crowther in McMullen County is said to be from the Cook Mountain formation of the Eocene period. At Gonzales in Gonzales County, gas has been obtained probably from the Yegua formation of the Eocene. The production at Piedras Pintas in Duval County is reported to be from domes of the salt dome type. The large gas flow from wells at White Point in San Patricia County may also be from a structure of the salt dome type.

Geological Investigations in the Petroleum Fields of Texas—At no time in the history of the petroleum industry have more careful or painstaking geological investigations been made than are now being made in the petroleum fields of Texas. In these investigations attention is being given not only to surface geology, but through the study of well cuttings and logs to sub-surface geology. In addition to the geological work of the Federal and State Governments in these fields, investigations are being made by a large number of geologists, working either independently or in the employ of the progressive oil companies, by whom data on the geology of these fields is being very rapidly assembled, and

to whom is due an important part in the remarkable developments that have taken place in this industry in recent years.

Derricks in Colombia, S. A.—It is interesting to note how the gas and oil men overcome some of the many problems that confront them in their operations to find oil and gas in

Fig. 235—AN OIL WELL IN COLOMBIA DRILLS WITH A MAHOGANY DERRICK

different parts of the globe. In the second edition of this book an article appeared telling about drilling for gas on the ice of Lake Erie. Fig. No. 235 shows a flowing oil well owned by the Tropical Oil Co., in Colombia, South

America. This field is located 400 miles inland near the Magdalene River.

Here the operators found it too expensive to ship in the derrick timbers, so used the most common wood at hand—mahogany. The derrick throughout is made of hand-sawed mahogany. The derrick is 96 feet high.

In further describing the field, there are four or five sands. Well No. 1, shown in Fig. 235, is flowing oil from the lower sand at a depth of 2100 feet, which has a Be. gravity of 34. It is making from 4000 to 10,000 barrels of oil daily. There is no gas in the oil, yet when the well was capped and shut in —which operation required six hours' work—the oil showed a pressure of 300 lbs. Well No. 2, of the same company, was drilled into one of the upper sands at a depth of 1500 feet, which flowed oil of an 18 Be. gravity.

The oil from Well No. 1 carries about 20 per cent. of gasoline, yet there is practically no gas in the well.

Laying Sea Loading Lines—While this article describes the laying of oil lines out into the ocean, the same method can be applied to the laying lines across wide rivers such as the Mississippi. It might be added that a few years ago an eight-inch line was laid across Niagara River at Buffalo, N. Y. In this case the hauling power was a locomotive on the New York Central tracks, at right angles to the river edge.

At Palo Blanco, Mexico, the Island Oil and Transport Corporation laid two eight-inch lines from the shore out a distance of 7280 feet, where the water reached a depth of 37 feet. Each line was made up of 36-pound wrought-iron screw pipe and the joints were river-clamped a distance of 2000 feet through the surf.

To accomplish the work a thirty-inch gauge special railway was laid directly inland and the pipe was screwed

Fig. 236—SEA LOADING LINE

TABLE

VALUE IN CENTS PER M. C. F. OF VARIOUS PRICES AND

Degrees Baume	Oil B. t. u. per Barrel	1050B. t. u. Gas Equiv. Cu. Ft. in 1 Barrel Oil	OIL AT			
			$ .50	$ .55	$ .60	$ .65
10	6,442,006	6135.244	8.16c	8.98c	9.79c	10.60c
11	6,417,868	6112.255	8.19	9.01	9.82	10.63
12	6,393,970	6089.495	8.22	9.04	9.86	10.67
13	6,370,035	6066.700	8.24	9.07	9.89	10.71
14	6,345,324	6043.166	8.27	9.10	9.93	10.75
15	6,323,180	6022.076	8.30	9.13	9.96	10.78
16	6,301,512	6001.440	8.33	9.16	10.00	10.82
17	6,279,576	5980.549	8.36	9.20	10.04	10.86
18	6,257,371	5959.401	8.39	9.23	10.07	10.90
19	6,234,708	5937.817	8.42	9.26	10.10	10.94
20	6,212,534	5916.699	8.45	9.29	10.13	10.98
21	6,192,950	5898.048	8.48	9.32	10.17	11.02
22	6,173,500	5879.524	8.51	9.36	10.20	11.06
23	6,153,426	5860.406	8.53	9.39	10.24	11.10
24	6,133,486	5841.415	8.57	9.42	10.28	11.14
25	6,113,495	5822.376	8.60	9.46	10.32	11.17
			OIL AT			
			$ 1.15	$ 1.20	$ 1.25	$ 1.30
10	6,442,006	6135.244	18.74c	19.56c	20.37c	21.19c
11	6,417,868	6112.255	18.81	19.63	20.45	21.27
12	6,393,970	6089.495	18.88	19.71	20.53	21.35
13	6,370,035	6066.700	18.95	19.78	20.60	21.43
14	6,345,324	6043.166	19.03	19.86	20.68	21.51
15	6,323,180	6022.076	19.10	19.93	20.76	21.59
16	6,301,512	6001.440	19.16	20.00	20.83	21.66
17	6,279,576	5980.549	19.23	20.07	20.90	21.74
18	6,257,371	5959.401	19.30	20.14	20.97	21.81
19	6,234,708	5937.817	19.37	20.21	21.05	21.89
20	6,212,534	5916.699	19.44	20.28	21.13	21.97
21	6,192,950	5898.048	19.50	20.35	21.19	22.04
22	6,173,500	5879.524	19.56	20.41	21.26	22.11
23	6,153,426	5860.406	19.62	20.48	21.33	22.18
24	6,133,486	5841.415	19.69	20.54	21.40	22.25
25	6,113,495	5822.376	19.75	20.61	21.47	22.33

Formula $\frac{B \times D}{A} = E$ A = B. t. u. in 1 Bbl. B = 1050 B. t. u.

D = Price of 1 Bbl. Oil. E = Value M. C. F. of Gas.

No. 113

1050 B. t. u. GAS WITH OIL AT GRAVITIES BAUME

OIL AT

$ .70	$ .75	$ .80	$ .85	$ .90	$ .90	$ 1.00	$ 1.05	$ 1.10
11.42c	12.23c	13.04c	13.86c	14.67c	15.48c	16.30c	.17.11c	17.93c
11.46	12.27	13.08	13.91	14.72	15.54	16.36	17.18	18.00
11.50	12.32	13.13	13.96	14.77	15.60	16.42	17.24	18.06
11.54	12.36	13.18	14.01	14.82	15.66	16.48	17.30	18.13
11.58	12.41	13.23	14.06	14.88	15.72	16.55	17.37	18.20
11.62	12.46	13.28	14.11	14.93	15.78	16.60	17.44	18.27
11.66	12.50	13.33	14.16	14.98	15.83	16.66	17.50	18.33
11.70	12.54	13.38	14.21	15.04	15.88	16.72	17.56	18.39
11.75	12.58	13.42	14.26	15.10	15.94	16.78	17.62	18.46
11.79	12.62	13.47	14.31	15.15	16.00	16.84	17.68	18.53
11.85	12.66	13.51	14.35	15.20	16.06	16.90	17.75	18.59
11.87	12.71	13.56	14.40	15.25	16.11	16.95	17.80	18.65
11.91	12.76	13.61	14.45	15.30	16.60	17.00	17.86	18.71
11.95	12.81	13.65	14.50	15.36	16.21	17.06	17.92	18.77
11.99	12.85	13.70	14.55	15.41	16.26	17.12	17.98	18.83
12.03	12.90	13.75	14.61	15.47	16.32	17.18	18.03	18.89

OIL AT

$1.35	$1.40	$1.45	$1.50	$1.55	$1.60	$1.65	$1.70	$1.75
22.00c	22.82c	23.63c	24.45c	25.26c	26.08c	26.89c	27.71c	28.52c
22.09	22.90	23.72	24.54	25.36	26.18	26.99	27.81	28.63
22.17	22.99	23.81	24.63	25.45	26.27	27.09	27.92	28.74
22.25	23.08	23.90	24.72	25.55	26.37	27.20	28.02	28.84
22.34	23.17	23.99	24.82	25.65	26.48	27.30	28.13	28.06
22.42	23.25	24.08	24.91	25.74	26.57	27.40	28.23	29.06
22.49	23.33	24.16	24.99	25.83	26.66	27.49	28.33	29.16
22.57	23.41	24.24	25.08	25.92	26.75	27.59	28.43	29.26
22.65	23.49	24.33	25.17	26.01	26.85	27.69	28.53	29.36
22.73	23.58	24.42	25.26	26.10	26.94	27.79	28.63	29.47
22.82	23.66	24.51	25.35	26.20	27.04	27.89	28.73	29.58
22.89	23.74	24.58	25.43	26.28	27.13	27.98	28.82	29.67
22.96	23.81	24.66	25.51	26.36	27.21	28.06	28.91	29.76
23.03	23.89	24.74	25.59	26.45	27.30	28.15	29.01	29.86
23.11	23.97	24.82	25.68	26.53	27.39	28.25	29.10	29.96
23.19	24.04	24.90	25.76	26.62	27.48	28.34	29.20	30.06

*Courtesy of Board of Public Utilities of Los Angeles, Calif., 8th Annua Report, June 30, 1917.

Fig. 237—LINE ON CARS LOOKING TOWARD GULF
Note river clamps on every joint

Fig. 238—GUIDE THROUGH WHICH LINE WAS DRAWN
Note position of steamer and tug

together along side of the railway, then hoisted upon special wooden cars, one car to two joints of pipe in length. The top of the cars were built with a trough in which the pipe laid. Great care was used to line up the railway with point in the ocean where the end of the line would rest. To do this a steamer and a tug were anchored at the desired point and the railway was laid in a direct line to the anchorage. At a

Fig. 239—LINE ON CARS
Note targets to aid steamer to pull line in a straight line off shore

point where the railway approached the surf, the track was laid with considerable grade so that the cars could be run out from under the pipe before they reached the water.

The head end of the line was laid into a specially built sled which prevented the line from running into the sandy bottom while being pulled seaward. A barrel for a buoy was tied to this barge to mark the location of the end of the line after being laid.

Fig. 240—BRIDLE ON PIPE TO PULL LINE WITH A 1¼-INCH CABLE

Fig. 241—END OF SEA LINE WITH FLANGE TO ATTACH FLEXIBLE HOSE

When the pipe line was ready, a $1\frac{1}{2}$ inch steel line was passed in from the S. S. Yarmouth and tied to the end of it. The Yarmouth was assisted by the tow-boat Harsteele. The latter was used to assist the Yarmouth in going straight ahead.

Fig. 242—CURVE IN RAILWAY TRACK WHERE CARS WERE TAKEN FROM UNDER PIPE JUST BEFORE PIPE ENTERS THE WATER

The operation was very successful, as it required but fifty-five minutes from the time the steamers started to pull until the signal was given to stop.

The loading lines lay in the bottom of the Gulf and have an eight-inch flexible hose attached to the end of each line that also lays on the bottom of the Gulf, but has a cable attached to them which are in turn tied to a buoy at the loading berth. When a tanker comes into the berth to load, it drops anchor on both sides forward, then runs lines aft to specially placed buoys to pull it in position so the flexible hose can be

hoisted aboard to connect with the loading connection on the ship.

The first boat was loaded with one line at the rate of 3000 barrels per hour.

Fig. 243—PULLING CABLE ASHORE FROM SHIP

Fig. 244—TWO EIGHT-INCH LINES FLOWING 80,000 BARRELS OF OIL PER DAY. SAME LINES AS SHOWN IN Fig. 234, Page 672.

Fig. 240. OBISPO OIL CO. GUSHER AT MARICOPA FLAT, CAL.
BUFFER USED TO HOLD DOWN THE SPRAY AND GASES. THIS ASSISTS IN SAVING GAS

Waste of Gas from Oil Wells—That waste of gas in the oil business is necessary is to be admitted. It is also true that there is a large amount of unnecessary waste. It is of this waste that this article deals.

It would be out of the question to attempt to put in figures an estimate of the annual loss from gas flowing from oil wells and from oil tanks. If these figures were actually known, no one would believe them when read.

In travelling through many of the most well-known fields the author has had opportunity of noting the waste of gas, and in some fields the methods pursued to save the gas formerly wasted.

In Kentucky fields the waste of gas from oil tanks, after the fields are fairly well drilled, is a serious factor. There is no reason why a special top could not be installed on top of the tanks and a suction line under one or two inches of mercury vacuum, connected to same, would not make a tremendous saving. In the Big Sinking field alone there are probably a hundred oil tanks, mostly of small size, which if equipped as above suggested the saving in gasoline and gas would create a new income of no small size. In this field the oil wells do not run over four or five hundred barrels in size when first drilled in but the oil is very high in gasoline.

The low vacuum on the top of the tank would not necessitate the use of vacuum pumps unless it was desired to force the gas any distance, as high pressure blowers would serve the purpose. Likewise this vacuum would not rob the oil and lower the gravity to any noticeable extent.

It would be necessary to treat the gas either by the compression or absorption process to obtain the gasoline.

The absorption process is successfully worked under very low pressure and is being used more and more every day.

In the event of anyone desiring to determine just how much gas was obtainable from one or more tanks, it would be advisable to first install a high-pressure blower and make a

careful test with the aid of same for volume, and then make a careful analysis or practical test with a small absorber.

In fact after placing the air-tight top on a tank, connecting same by pipe line to a high-pressure blower, one would proceed the same as though he were testing the casinghead gas from a group of oil wells, for gasoline content and volume.

Both the Federal Government (through the Bureau of Mines) and the State Government, have done a great deal of good in changing the methods of drilling in large-sized oil wells where a large vein of gas is encountered. The old methods of allowing gas wells in oil sands to blow open until the gas is exhausted is practically done away with. If the gas sand is distinct from the oil sand it is mudded off. If a large flow of gas is anticipated before the oil sand is reached by the drill, gate valves larger in size than the casing are installed on the casing by using a swage nipple, and when the gas is struck, the valve can be closed as soon as the tools are removed from the hole. If the gas comes from a separate vein it is mudded off. If it comes from an oil sand it is used as a gas until the well starts flowing oil.

Without the many regulations now imposed on the oil operator, the waste of gas from this source would be a very large factor, but the invisible waste, such as comes from oil tanks, is even a larger factor. When gas flows from a six or eight-inch hole it is plainly visible. This waste seldom lasts but a few days. When gas flows from a open oil tank it is invisible. This is due to the large diameter of the tank compared with the well and to the fact that the volume is smaller, but this waste continues day in and day out throughout the year or until the wells become exhausted or provision is made to recover it. It is one of the big leaks encountered in the oil business.

When oil is struck every one is in a hurry to get up tankage and to run the oil. After the tanks are set up and con-

Fig. 247—THE SMITH OIL AND GAS SEPARATOR

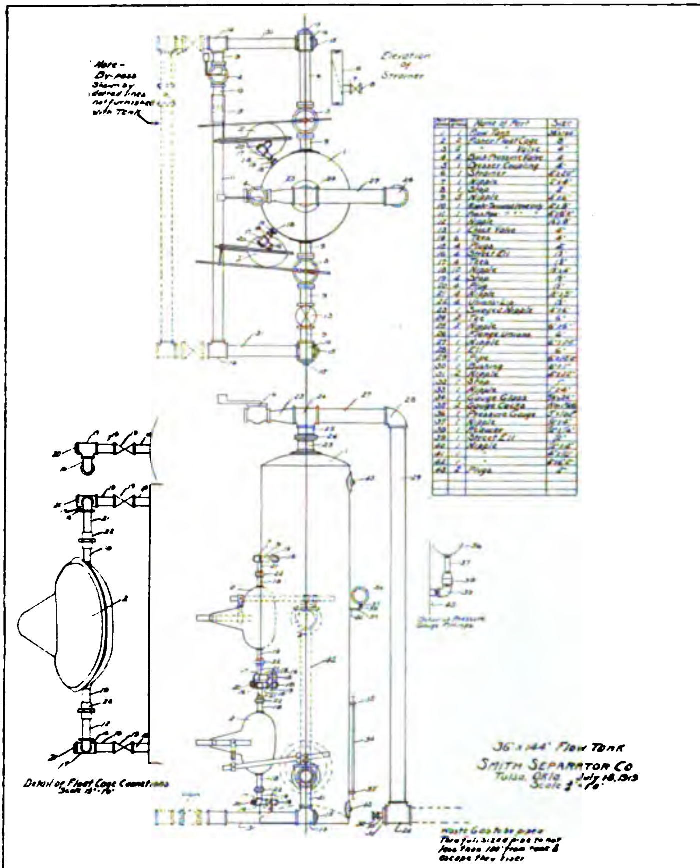
Elevation of Strainer
Name of Part
Size
36" x 144" Flow Tank
Smith Separator Co
Tulsa, Okla.
Detail of Float Cage Connections

Fig. 248

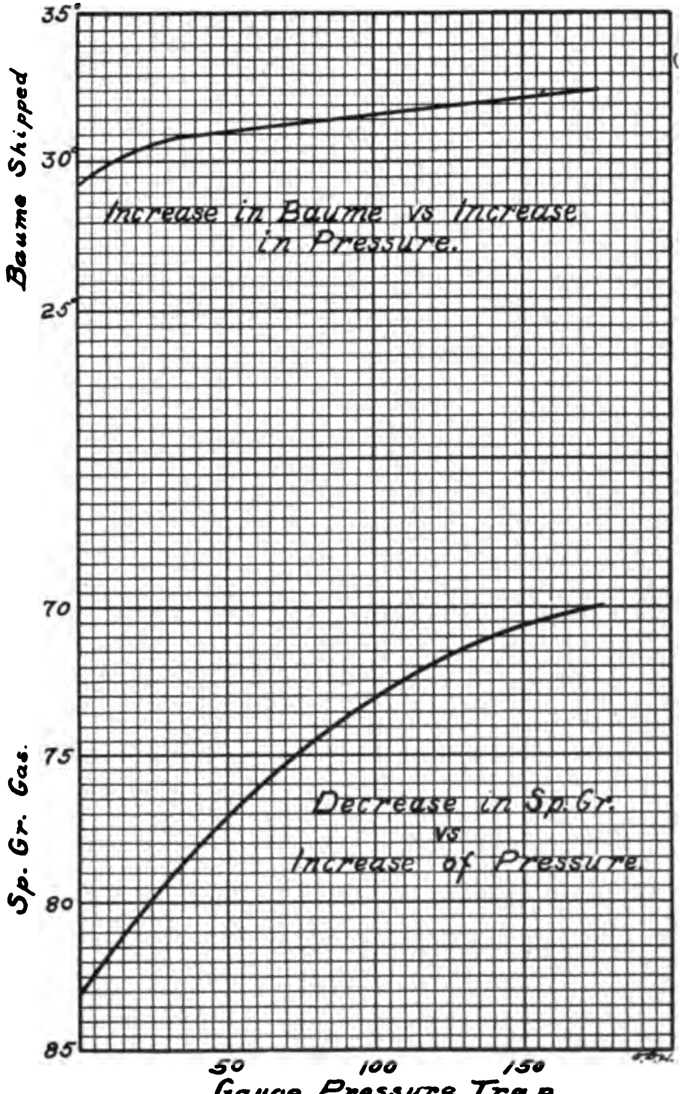

Fig. 250—CHARTS SHOWING THE GRAVITY CHANGES IN OIL AND GAS WHEN THE GAS IS SEPARATED FROM THE OIL COMING FROM AN OIL WELL

TABLE No. 114

Table Showing Amount of Gas Conserved by Installing High Pressure Traps.

Pres. on Trap	Well Pres.	Flow Plug	Daily Prod. Oil	Baume in Trap	Baume in Tank Inlet	Baume Shipped	Gas Cu. Ft. per Day 14.65	Sp. Gr. of Gas	Remarks
No trap	380 lb.	5/8"	1181 bl.	No trap	29.9°	29.3°	No Meter	.83	Gas dense white cloud
36 lb.	380 lb.	5/8"	1175 bl.	31.3°	31.3°	30.9°	1,285,000	.79	Marked decrease in color of gas
74 lb.	385 lb.	5/8"	1205 bl.	31.9°	31.8°	31.2°	1,255,000	.75	Nearly all white color of gas eliminated
177 lb.	390 lb.	5/8"	1190 bl.	31.7°	32.2°	31.1°	1,685,000	.70	

nected with the pipe line, why not continue the work and provide for saving and using the waste gas from the tanks?

A great many of the large companies in the mid-continent and California fields are using large gas traps to separate the gas from the oil. New experiments are constantly being tried to find a better method than the one in use. In one

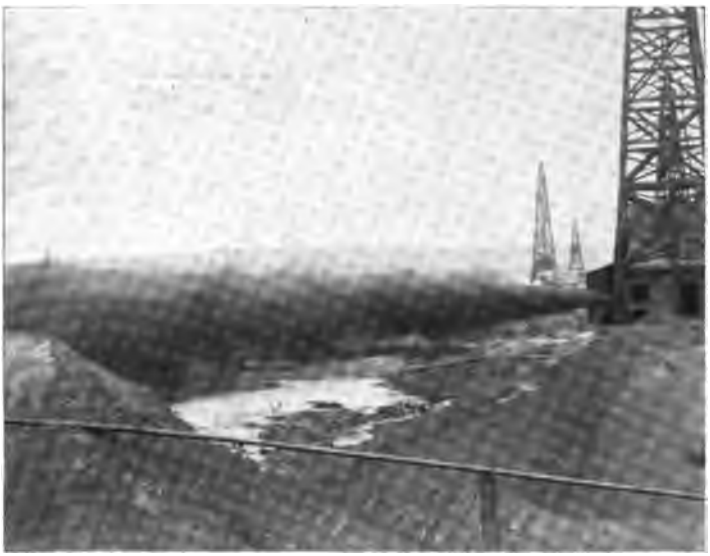

Fig. 251—BLOWING OIL INTO AN OIL SUMP BY AID OF GAS. OWNED BY THE MIDLAND OIL CO., MARICOPA, CAL.

field near Los Angeles the author saw one oil well flowing many hundreds of barrels of oil daily, which passed through a gas trap, and several million cubic feet of gas of high quality was taken from the oil. This gas was then run to a gasoline compression plant where two to three gallons of gasoline were taken from a thousand cubic feet of gas.

Several drawings of oil traps are shown with this article. Some were being successfully used in California, others in Texas, Oklahoma and Mexico.

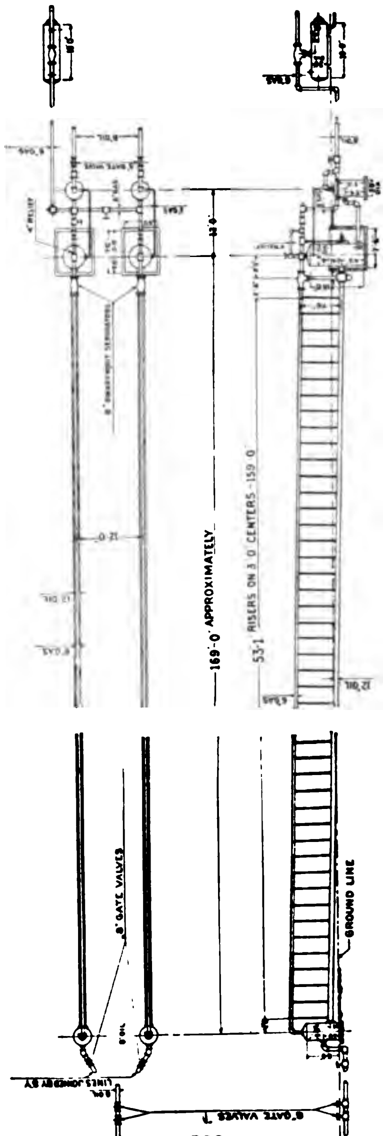

Fig. 252—*ONE TYPE OF OIL AND GAS SEPARATOR, USED EXTENSIVELY IN MEXICO*

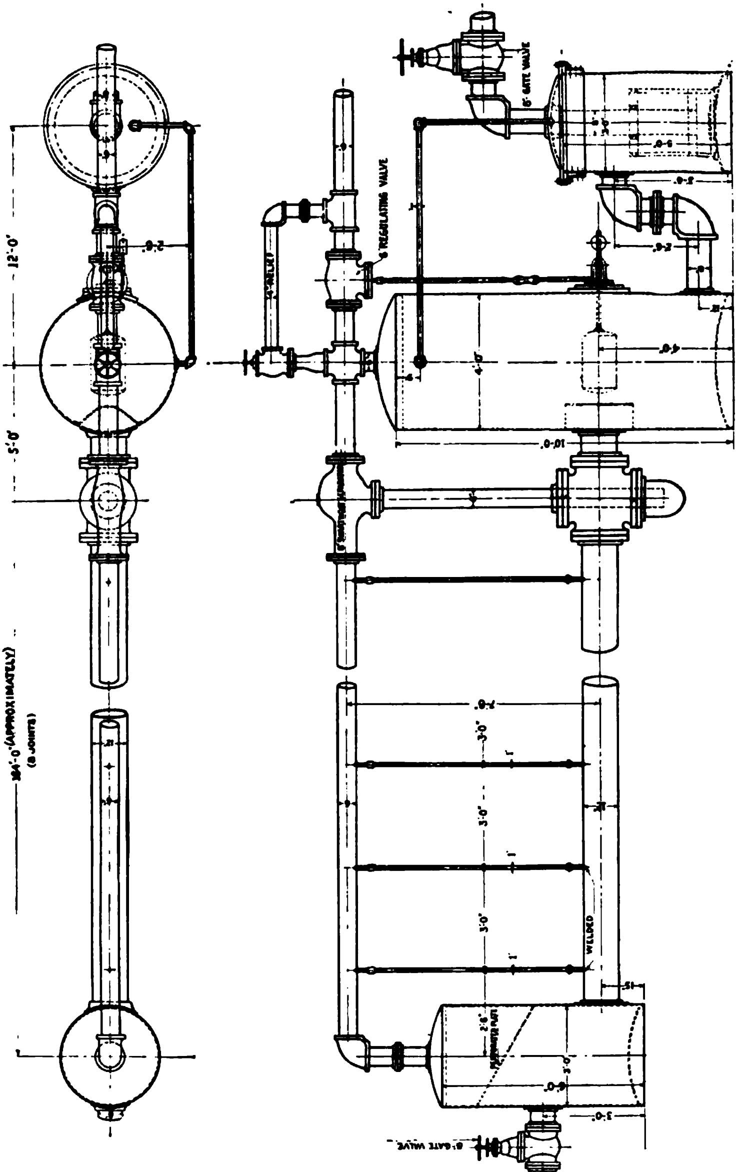

Fig. 253—SAME AS Fig. 252, SHOWING DETAILS OF CONSTRUCTION

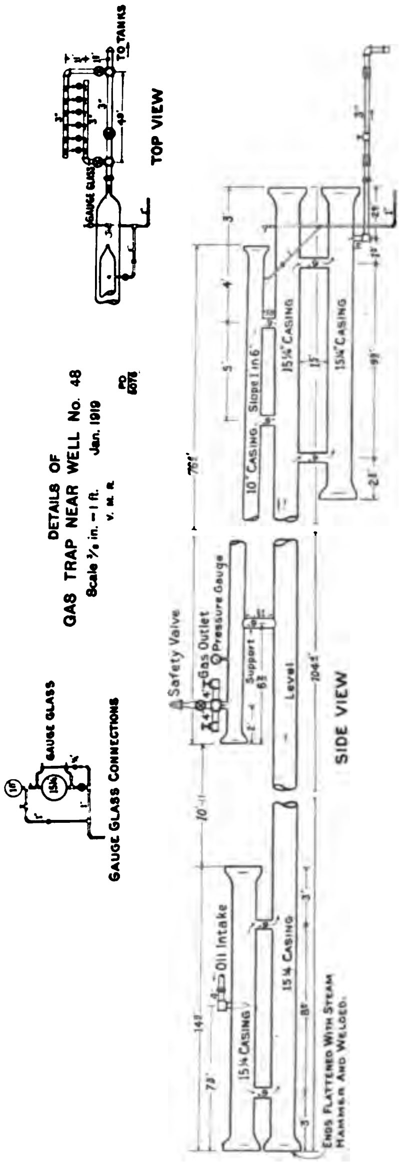

Fig. 254—A GAS AND OIL SEPARATOR USED SUCCESSFULLY IN THE CALIFORNIA OIL FIELDS

In designing an oil trap there are two main things to endeavor to accomplish, viz., to slow down the velocity of the flowing oil in order to give the gas a chance to escape, and to break up the flowing oil by the aid of baffle plates at the time of slowing down the flow. It is more difficult to release the gas from the oil if it is under a pressure. The lower the

Fig. 255—ONE TYPE OF AN OIL TRAP

pressure the easier it is to release the gas globules from the oil. The slower the oil flows the easier the gas rises to the surface.

The true way to determine the efficiency of a trap is to install a second trap at a point further along on the pipe line. Just because one is obtaining several million cubic feet of gas from a trap installed on a lead line from a large oil well, it

does not necessarily follow that all the gas is obtained from the oil that is possible. In one instance that came to the author's notice, a certain company was obtaining several million cubic feet of gas from lead line and was under the impression that the gas that was taken from the oil in the trap was all that could be obtained until they installed a second trap about a half a mile further along on the pipe line, which they increased it an additional million cubic feet of gas daily.

In the foregoing paragraph large wells and large volumes of gas are dealt with. This is due to the fact that this information came from some of the larger companies that had large oil wells. The general tendency is to correct the greatest waste first, in the same manner as with the introduction of the casinghead gas business, when only large volumes carrying high gasoline content were bothered with. In this particular business gas carrying a very small gasoline content is eagerly sought for these days.

This article should be of just as great an interest to the small oil operator with his fifty barrel wells as to the large ones having ten thousand barrel wells.

PART TWENTY-TWO

MISCELLANEOUS

TABLE No. 115

Showing Beaume Degrees, Specific Gravity and Weight per Gallon of Oil of 60 Deg. Fahr.

Beaume Degrees	Specific Gravity	Lb. in Gallon	Beaume Degrees	Specific Gravity	Lb. in Gallon	Beaume Degrees	Specific Gravity	Lb. in Gallon
10	1.0000	8.33	37	0.8383	6.99	64	0.7216	6.03
11	0.9929	8.27	38	0.8333	6.95	65	0.7179	6.00
12	0.9859	8.21	39	0.8284	6.91	66	0.7142	5.97
13	0.9790	8.16	40	0.8235	6.87	67	0.7106	5.94
14	0.9722	8.10	41	0.8187	6.83	68	0.7070	5.91
15	0.9655	8.05	42	0.8139	6.80	69	0.7035	5.88
16	0.9589	7.99	43	0.8092	6.76	70	0.7000	5.85
17	0.9523	7.94	44	0.8045	6.72	71	0.6965	5.82
18	0.9459	7.88	45	0.8000	6.68	72	0.6930	5.79
19	0.9395	7.83	46	0.7954	6.64	73	0.6896	5.77
20	0.9333	7.78	47	0.7909	6.60	74	0.6863	5.74
21	0.9271	7.73	48	0.7865	6.57	75	0.6829	5.71
22	0.9210	7.68	49	0.7821	6.53	76	0.6796	5.63
23	0.9150	7.63	50	0.7777	6.49	77	0.6763	5.65
24	0.9090	7.58	51	0.7734	6.46	78	0.6730	5.63
25	0.9032	7.54	52	0.7692	6.42	79	0.6698	5.60
26	0.8974	7.49	53	0.7650	6.39	80	0.6666	5.57
27	0.8917	7.44	54	0.7608	6.36	81	0.6635	5.55
28	0.8860	7.39	55	0.7576	6.32	82	0.6604	5.51
29	0.8805	7.34	56	0.7526	6.29	83	0.6573	5.48
30	0.8750	7.29	57	0.7486	6.26	84	0.6542	5.45
31	0.8695	7.25	58	0.7446	6.22	85	0.6511	5.42
32	0.8641	7.21	59	0.7407	6.19	86	0.6481	5.40
33	0.8588	7.16	60	0.7368	6.16	87	0.6451	5.38
34	0.8536	7.12	61	0.7329	6.13	88	0.6422	5.36
35	0.8484	7.07	62	0.7290	6.10	89	0.6392	5.33
36	0.8433	7.03	63	0.7253	6.07	90	0.6363	5.30

TABLE No. 116

Melting Point and Expansion of Metals

Substance	Melting Point	Lineal Expansion of Metals
	Deg. fahr.	Produced by raising their temperature from 32 to 212 deg.
	Kent	
Aluminum	1247 (1157)	
Bronze	1652 (1692)	
Copper	2102 (1929)	One part in 581
Gold	2192 (1913)	" " " 682
Cast Iron	1922 to 2382	" " " 812
Wrought Iron	2732 to 2912	" " " 812
Lead	(618)	" " " 351
Platinum	3227	" " " 1100
Silver	1832 (1733)	" " " 524
Steel	2372 to 2552	" " "
Tin	540 (442)	" " " 403
Zinc	786 (779)	" " " 322

Beaume Scale and Specific Gravity Equivalent—The instruments used are a hydrometer and a standard thermometer. The hydrometer, which is a glass column marked with graduations from 10 to 100, was invented by Antoine Beaume, a French chemist, and the scale on the instrument has always borne his name. The hydrometer, when placed in a jar or a bottle of oil, sinks to the point on the scale which indicates the gravity in degrees Beaume. The basis of temperature for testing oil is 60 deg. fahr., and for oil at a greater or less temperature, variations must be calculated. Hydrometers are usually provided with a special scale for figuring temperature variations. The specific gravity is found by dividing 140 by 130 plus the Beaume degrees. For example: if the hydrometer registers 30 deg., this added to 130 equals 160, which divided into 140, shows specific gravity .875.

TABLE No. 117

SPECIFIC GRAVITIES OF LIQUIDS AT 60 DEG. FAHR.

Liquid	Specific Gravity	Liquid	Specific Gravity
Rigolene	.625	Olive Oil	.92
Naphtha	.690	Rape Oil	.92
Naphtha No. 2	.707	Linseed Oil	.94
Sulphuric Ether	.720	Water	1.00
Alcohol (pure)	.794	Muriatic Acid	1.20
Refined Petroleum	.805	Nitric Acid	1.22
Alcohol (95%)	.816	Sulphuric Acid	1.85
Turpentine	.870	Mercury	13.58

TABLE No. 118

WEIGHT AND TENSILE STRENGTH OF WOOD, IRON AND OTHER MATERIALS

Material	Weight per Cubic Foot Pounds	Tensile Strength Pounds per Square Inch
White Ash	38	11000
Hickory	53	12800
Chestnut	41	10500
Hemlock	25	8700
White Oak	48	10500
Red Oak	40	10000
Yellow Pine	45	12600
Oregon Pine	40	12000
Norway Pine	34½	11000
White Pine	25	10000
Redwood	....	7000
Spruce	125	10000
Whitewood	....	8500
Walnut	38	9286
Cast Iron	450	15000 to 24000
Malleable Iron	450	25000 to 35000
Copper	550	20000 to 30000
Aluminum	167	15000 to 24000
Wrought Iron	485	40000 to 50000
Wrought Steel	490	60000 to 80000
Iron Pipe	....	35000 to 45000
Steel Pipe	....	50000 to 65000
Cement	75 to 90	350
Sand	115	....
Limestone	168	....

TABLE No. 119

WEIGHTS OF ROUND IRON AND STEEL PER LINEAL FOOT IN POUNDS

Size in Inches	Iron	Steel
1/4	.164	.167
5/16	.256	.261
3/8	.368	.375
7/16	.501	.511
1/2	.654	.667
9/16	.828	.845
5/8	1.023	1.043
11/16	1.237	1.262
3/4	1.473	1.502
7/8	2.004	2.044
1	2.618	2.67
1 1/8	3.313	3.379
1 1/4	4.091	4.173
1 3/8	4.95	5.049
1 1/2	5.09	6.008
1 5/8	6.913	7.051
1 3/4	8.018	8.078
1 7/8	9.204	9.388
2	10.470	10.679
2 1/8	11.820	12.056
2 1/4	13.250	13.515
2 3/8	14.770	15.065
2 1/2	16.36	16.69
2 5/8	18.04	18.40
2 3/4	19.8	20.2
2 7/8	21.64	22.07
3	23.56	24.03

CONVERSION TABLES

COMPOUND UNITS

Metric to U. S.

1 kilogram per meter=0.6720 lb. per foot.
1 kilogram per sq. centimeter=14.223 lb. per sq. inch.
1 kilogram per sq. meter=0.2048 lb. per sq. foot.
1 kilogram per cubic meter=0.0624 lb. per cu. ft.
1 kilogram-meter=7.233 foot pounds.
1 cheval vapeur (metric h. p.)=0.986 horsepower.
1 kilowatt=1.340 horsepower.
1 kilo. per cheval=2.235 lb. per h. p.

U. S. to Metric

1 lb. per ft.=1.4882 kilograms per meter.
1 lb. per sq. inch=0.0703 kilograms per sq. centimeter.
1 lb. per sq. ft.=4.8825 kilograms per sq. meter.
1 lb. per cu. ft.=16.0192 kilograms per cu. meter.
1 foot pound=.01383 kilogram-meter.
1 horsepower=1.014 cheval-vapeur (metric h. p.)
1 horsepower=0.746 kilowatt.
1 lb. per horse power=0.447 kilos per cheval.

MEASURES OF HEAT.

Heat Intensity

Temp. Centigrade (temp. fahr. — 32 deg.) 5/9.
Temp. fahrenheit (temp. C. x 9/5 + 32 deg.)

Heat Quantity

A kilogram calorie=3.968 British thermal units.
A pound calorie=1.8 British thermal units.
A British thermal unit=0.252 kilogram calorie.
A British thermal unit=0.555 pound calorie.

MEASURES OF VOLUME AND CAPACITY

Metric to U. S.

1 cu. centimeter=0.061 cu. inch.
1 cu. meter=35.316 cu. feet.
1 cu. meter=1.308 cu. yards.
1 liter 1 cu. decimeter= 61.023 cu. inch.

Liquid Measure

1 liter=1.0567 quart
1 liter=0.2642 gallon.
1 cu. meter=264.17 gallon.

Dry Measure

1 liter=0.908 quart
1 hectoliter=2.8375 bushels.

U. S. to Metric

1 cu. inch=16.39 cu. centimeters.
1 cu. ft.=0.0283 cu. meter.
1 cu. yd.=0.7645 cu. meter.
1 cu. ft.=28.32 liters.

Liquid Measure

1 quart=0.9463 liters.
1 gallon=3.7854 liters.
1 gallon=0.0038 cu. meter.

Dry Measure

1 quart=1.1013 liters.
1 bushel=0.3524 hectoliters.

WEIGHTS

Metric to U. S.

1 milligram=0.0154 grain.
1 gram=15.432 grain
1 kilogram=2.2046 lb. (avoir.)
1 metric ton=1.1023 net tons.
1 metric ton=0.9842 gross tons.

U. S. to Metric

1 grain=64.80 milligrams.
1 grain=0.0647 gram.
1 lb. (avoir.)=0.4536 kilogram.
1 net ton=0.9076 metric ton.
1 gross ton=1.0161 metric ton.

MEASURES OF LENGTH

Metric to U. S.

1 millimeter = 0.03937 inch.
1 centimeter= 0.3937 inch.
1 meter =39.37 inch.
1 meter = 3.2808 feet.
1 kilometer = 0.6214 mile.

U. S. to Metric

1 inch =25.4 millimeters.
1 inch = 2.54 centimeters.
1 inch = 0.0254 meter.
1 foot = 0.3048 meter.
1 mile = 1.609 kilometers.

MEASURES OF SURFACE

Metric to U. S.

1 sq. millimeter= 0.00155 sq. inch.
1 " centimeter= 0.155 " "
1 " meter =10.764 " ft.
1 " " = 1.196 " yds.
1 hectare = 2.471 acres.
1 " = 0.00386 sq. mile.
1 sq. kilometer = 0.3861 " "

U. S. to Metric

1 sq. inch =645.14 sq. millimeters.
1 " " = 6.452 " centimeters.
1 " foot = 0.0929 " meter
1 " yard= 0.8361 " "
1 acre = 0.4047 hectares.
1 sq. mile =259.00 "
1 " " = 2.59 sq. kilometers.

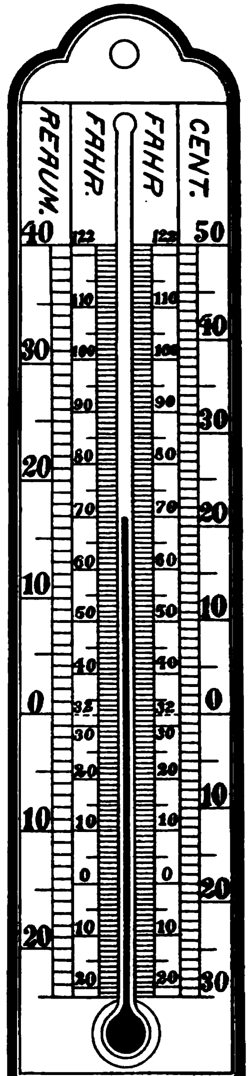

Fig. 256

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